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Forest Pest Management Institute Bibliography (1977-1982)

Compiled by K.B. Griffiths

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K.B. Griffiths

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CANADIAN FORESTRY SERVICE
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FOREWORD

This Bibliography represents an attempt to list all Forest Pest Management Institute Information Reports and journal articles that have been published since the formation of FPMI in 1977. The Bibliography is broken into six major subject areas to make the list easier to use - Biological Control Agents, Physiological and Genetic Mechanisms, Complementary Research, Application Technology, Pest Products - Efficacy and Use Strategies, and Environmental Impact and Chemical Accountability. The author index provides a list of all authors.

This report is not intended as a list of available publications, as many of the older ones and a few of the more popular recent publications are out of print. Enquiries concerning any of the publications listed here should be addressed to:

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BIOLOGICAL CONTROL AGENTS: BACTERIAL PATHOGENS

Fast, P.G. 1977. *Bacillus thuringiensis* δ-endotoxin: On the relative roles of spores and crystals in toxicity to spruce budworm (Lepidoptera: Tortricidae). Can. Entomol. 109:1515-1518.

High proportions of spores increase toxicity only LD_{50} - LD_{60}.

Milne, R.; Murphy, D.W.; Fast, P.G. 1977. *Bacillus thuringiensis* δ-endotoxin: An improved technique for separation of crystals from spores. J. Invert. Pathol. 29: 230-231.

A generally applicable efficient technique for separating spores from crystals is reported.

Morris, O.N. 1977. Compatability of 27 chemical insecticides with *Bacillus thuringiensis* var. *kurstaki*. Can. Entomol. 109: 855-864.

The compatibility of Bacillus thuringiensis (B.t.) with 27 chemical insecticides representing organophosphorus and carbamate insecticides, pyrethrins, chlordimeform, urea derivative, and antifeedant were studied by way of their effects on germination of the bacterial spores, replication of vegetative cells and spore staining, and refractive index characteristics.

The results showed that: (1) Carbamates were generally more compatible with Bacillus thuringiensis than were the other insecticide groups tested. (2) Technical formulations were less harmful to the bacteria than wettable powders which were less harmful than emulsifiable concentrates. (3) Of the 27 pesticides, those most compatible with B.t. were Orthene®, Dylox®, Lannate®, Sevin®, Zectran®, and Dimilin®. These insecticides are considered recommendable for use in integrated control operations with Bacillus thuringiensis if the target insects are susceptible to them and provided that due regard is given to the environmental implications of their use.

Morris, O.N. 1977. Long term effectiveness of aerial application of commercial *Bacillus thuringiensis* -Orthene combination against the spruce budworm. Can. Entomol. 109: 1239-1248.

Bacillus thuringiensis (Dipel 36B) mixed with a sublethal concentration of acephate (Orthene) (O, S-dimethyl acetylphosphoramidothioate), an organophosphorous insecticide, was applied at 2.35-14 L/ha to white spruce (Picea glauca) and balsam fir (Abies balsamea) trees infested with spruce budworm, Choristoneura fumiferana (Clem.). The treatment rate was 20 Billion International Units of B. thuringiensis (B.t.) with or without 42 g active ingredient of acephate/ha.

The treatments had no deleterious effect on spruce budworm parasitism. The data indicate that the integrated approach using Bacillus thuringiensis - chemical pesticide combinations is a viable alternative to the use of chemical pesticides alone in spruce budworm control. Large scale testing is now warranted.

Fast, P.G. 1978. Laboratory bioassays of mixtures of *Bacillus thuringiensis* and chitinase. Can. Entomol. 110: 201-204.

Chitinase did not affect efficacy of B.t. in the seven days of the bioassay.

Fast, P.G.; Murphy, D.W.; Sohi, S.S. 1978. *Bacillus thuringiensis* delta-endotoxin: evidence that toxin acts at the surface of susceptible cells. Experientia 34: 762-763.

Enzymically activated δ-endotoxin of Bacillus thuringiensis covalently bound to Sephadex beads has the same effect on insect cells in tissue culture as free toxin. The effect is prevented by antitoxin antibody and heat denaturation and is not due to a nonspecific protein effect, the beads or toxin released from the beads. The toxin, therefore, probably acts at the cell surface.

Krywienczyk, J.; Dulmage, H.T.; Fast, P.G. 1978. Occurrence of two serologically distinct groups within *Bacillus thuringiensis* Serotype 3 ab. var. *kurstaki*. J. Invert. Pathol. 31: 372-375.

Two groups distinguishable on the basis of crystal serology have been identified within Bacillus thuringiensis var. kurstaki (serotype 3 ab). The toxicities of these two groups to Trichoplusia ni and Heliothis virescens expressed as T/H ratio also differed. It is suggested that serotype 3 ab be separated into two subgroups designated as K-1 and K-73.

Fast, P.G.; Milne, R. 1979. *Bacillus thuringiensis* parasporal toxin: dissolution of crystals with retention of toxicity. J. Invert. Pathol. 34: 319.

Krywienczyk, J.; Fast, P.G. 1980. Serological relationships of the crystals of *Bacillus thuringiensis* var. *israelensis*. J. Invert. Pathol. 36: 139-140.

Var. israelensis paraspores are serologically unrelated to crystals of the other B.t.s.

Morris, O.N. 1980. Report of the 1979 CANUSA Cooperative *Bacillus thuringiensis* B.t. spray trials. Forest Pest Manage. Inst. Inf. Rep. FPM-X-40. 150 pp.

In cooperative trials carried out in Newfoundland, Nova Scotia, New Brunswick, Quebec, Ontario, and the State of Maine, a total of 44,499 ha of spruce-fir forest were treated with various B.t. preparations at 20 BIU/ha. The aim of the applications was to limit defoliation to 50% of the current year's growth. Results of the applications showed that in balsam fir and white spruce stands, 55% of the treatments were effective; in red spruce 85% were effective. Of the products studied, Dipel 88 was most effective, followed by Thuricide, then Novabac. Cost estimates for the treatments ranged from 15.97/ha to 21.94/ha. Environmental studies indicated no adverse effects on nontarget organisms in the forest ecosystem.

Morris, O.N.; Hildebrand, M.J.; Armstrong, J.A. 1980. Preliminary field studies on the use of additives to improve deposition rate and efficacy of commercial formulations of *Bacillus thuringiensis* applied against the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Forest Pest Manage. Inst. Inf. Rept. FPM-X-32, 23 pp.

Results of the 1976 tests were inconclusive, due partly to an apparent collapse in budworm population densities in all plots. Deposit rates of active ingredients were poor due to clogging of spray nozzle systems.

In 1977, two treatments each of 10 Billion International Units (BIU) of Thuricide 16B + 56 g active ingredient (AI) acephate + 1% Uvitex ERN-P 1% + 0.02% Kelzan + 1% Uvitex ERN-P + 1% of Uvinol D519 in 4.7 litres per ha applied when larvae were at peak L_3 and L_4, were deposited at ground level at the rate of 15.9 BIU/ha, respectively and were both highly effective in terms of population density reduction and foliage protection. An acephate treatment applied at 56 g/ha (i.e., 6 to 10% of the operational rate) reduced larval population density but did not protect the trees from defoliation as effectively as did the combined B.t. - acephate treatments. The biocide treatments caused no apparent deleterious effect on budworm parasitism. Based on deposit efficiency and foliage protection criteria, double applications of the new tank mixes were considered highly effective for spruce budworm control.

Fast, P.G.; Martin, W.G. 1981. *Bacillus thuringiensis* parasporal crystal toxin: dissociation into toxic low molecular weight peptides. Biochem. & Biophys. Res. Comm. 95(3): 1314-1320.

Parasporal crystals of Bacillus thuringiensis can be dissociated into low molecular weight peptides (<5000 daltons) by dissolving them in 0.1 M N-morpholinopropane sulfonic acid buffer pH 7.8 containing 0.05 M dithiothreitol and 2M-4M KSCN, or by performic acid oxidation. The peptides obtained by dissolving in KSCN were still toxic to silkworm larvae.

Krywienczyk, J.; Dulmage, H.T.; Hall, I.M.; Beegle, C.C.; Arakawa, K.Y.; Fast, P.G. 1981. Occurrence of Kurstaki k-1 crystal activity in *Bacillus thuringiensis* subs. *thuringiensis Serova* (H1). J. Invert. Pathol. 37: 62-65.

Morris, O.N. 1981. Interaction of *Bacillus thuringiensis* var. *kurstaki* with selected emulsifiers, solvents and an organophosphate insecticide. Forest Pest Manage. Inst. Inf. Rep. FPM-X-44, 14 pp.

The compatibility of Bacillus thuringiensis var. kurstaki (B.t.) with 12 emulsifiers, 2 solvents and a commercial chemical insecticide were studied by way of their effects on spore germination, vegetative cell replication and physiological reactions.

Five additives, viz. EMCOL AL6940 and N-500B TOXIMUL - MP8, SPONTO - 541 and ATLOX 3409 F, at 1 ppm concentration significantly inhibited spore germination. All additives tested at this concentration inhibited vegetative cell replication. Mixtures of these 5 additives with B.t. should be avoided in practice.

The data indicate that 10,000 ppm of acephate has no apparent effect on several key physiological reactions of B. thuringiensis kurstaki.

Morris, O.N. 1981. Report on the 1980 cooperative *Bacillus thuringiensis (B.t.)* spray trials. Forest Pest Manage. Inst. Inf. Rep. FPM-X-48, 75 pp.

The cooperative CANUSA B.t. trials, which started in 1979, were continued in 1980 with the treatment of 100,413 hectares of balsam fir, Abies balsamea, white spruce, Picea glauca and red-black spruce, Picea rubens-Picea mariana stands in Eastern Canada and United States. The main aim was to limit defoliation to 50% of the current year's growth. The cooperating agencies in 1980 were Ontario, Quebec, Newfoundland and Labrador, Nova Scotia, and Maine.

Based on the proportions of treated areas acceptably protected, B.t. success rates in 1980 were 67% on white spruce, 99% on red-black spruce and 71% on balsam fir. Corresponding percentages for 1979 and 1980 combined were 90, 97 and 70. Data in 1980 from Quebec indicated that B.t. was no less effective than fenitrothion, and where B.t. failed to give satisfactory results in Maine, due to bad weather, Sevin-4-oil also performed poorly when applied at the same time and place. It is apparent that B.t. is now a credible alternative to chemical pesticides for spruce budworm control and should be recommended especially in environmentally sensitive areas. The two fully registered compounds, Thuricide 16B and Dipel 88 (4L), are equally effective.

Morris, O.N.; Hildebrand, M.J.; Moore, A. 1981. Comparative effectiveness of three commercial formulations of *Bacillus thuringiensis* for control of the spruce budworm, *Choristoneura fumiferana* (Clem.). Forest Pest Manage. Inst. Inf. Rep. FPM-X-47, 31 pp.

The efficacies of three aerially applied Bacillus thuringiensis (B.t.) products, Dipel 88®, a newly registered oil-based formulation, Thuricide 24B, an experimental water-based formulation, and Thuricide 16B , were compared against the spruce budworm, Choristoneura fumiferana (Clem.). All B.t. products were applied at the same dosage rate (20 Billion International Units/hectare), but Thuricide 24B was sprayed at 4.7 L/ha, and all the others at 9.4 L/ha. The Dipel vehicle (Dipel 88 without B.t.) was applied as a check.

The following conclusions were drawn from the results: 1) The B.t. treatments in these tests were not especially effective in terms of immediate insect kill but were highly effective against budworm defoliation. Dipel 88 is as effective against the budworm as Thuricide 16B and 24B applied at similar dosage levels. 2) The efficacy of Thuricide 24B applied at 4.7 L/ha was equivalent to that of Thuricide 16B applied at 9.4 L/ha. 3) There was no significant correlation between ground level droplet density and defoliation. A precise tree deposit assessment technique is sorely needed. 4) Dipel vehicle was not toxic to budworm larvae under field application conditions. 5) Millipore filter membranes were more efficient collectors of atomized B.t. than were Kromekote® cards. Oil-sensitive cards can be used as deposit collectors for oil-based B.t.

Preliminary biomass studies showed that measurements of population density in the year of treatment alone provide an incomplete assessment of the effects of B.t. on a budworm population.

Morris, O.N. 1982. Bacteria as Pesticides: Forest Applications. Pages 239-287 *in* E. Kurstak, ed. Microbial and Viral Pesticides. Marcel Dekker, New York.

Morris, O.N. 1982. Response of the spruce budworm, *Choristoneura fumiferana* (Clem.) to graded dosage rates and single vs double applications of *Bacillus thuringiensis* var. *kurstaki*. Forest Pest Manage. Inst. Inf. Rep., FPM-X-53, 19 pp.

The relationship between the effectiveness and dosage rate of Thuricide 32 BX and Dipel 88 aerially applied against the spruce budworm Choristoneura fumiferana (Clem.) was investigated. The application rates were 10, 20, 40, and 80 Billion International Units (BIU/ha) for both products. In addition, the efficacy of double versus single applications of the same dosage was compared.

The following conclusions were drawn from the results: 1. The efficacy of commercial Bacillus thuringiensis (B.t.) applied against the spruce budworm increases with dosage rates applied between 10 BIU and 40 BIU/ha in terms of population density reduction, but levels off after 40 BIU/ha. A dosage rate of 20 BIU/ha is suboptimal for consistently acceptable insect kill. Reduction in weight of surviving larvae is proportional to dosage applied; 2. Dipel, applied at rates up to 80 BIU/ha, has no significant deleterious effect on parasitism on budworm; 3. The efficacy of B.t. in terms of foliage preservation on balsam fir generally increases with dosage applied. The most effective economical dosage tested ranged between 20 and 40 BIU/ha; 4. Under the conditions of the test, double applications have no advantage over a single application of the same dosage; 5. Pending confirmation of these findings, it appears that an increase in operational dosage rate from 20 to 30 BIU/ha would give more consistently acceptable results.

Morris, O.N. 1982. Report of the 1981 cooperative *Bacillus thuringiensis (B.t.)* spray trials. Forest Pest Manage. Inst. Inf. Rep. FPM-X-58, 87 pp.

A total of 79,378 hectares of balsam fir and white, red and black spruce stands were treated with B.t. in 1981 using the registered products Thuricide 16B®, Thuricide 32B® and Dipel®88 (4L) , and to a limited extent, the experimental formulations, Thuricide 32BX, Thuricide 24B, and Futura 64B. Based on the proportions of treated areas reported as acceptably protected (50% or less defoliation), the overall success rate of registered B.t. products ranged from 88% to 100%. Success rates in white, red, and black spruce stands ranged from 85% to 100% but population densities were generally low in these stand types. The overall success rate in the more vulnerable balsam fir stands with moderate to high larval populations was 88%, representing an improvement in B.t. effectiveness over the 1979-1980 treatments which was 70%.

Analysis of the 1981 data indicated the following trends: 1. An operational dosage rate of 20 BIU/ha produces inconsistent results in terms of effectiveness. The application rate of 30 BIU/ha was consistently effective. 2. Ground deposit rates lower than 25 droplets/cm^2 produce inconsistent results. 3. Operational dosage rates of conventional chemical pesticides are only slightly more effective than B.t. applied at 30 BIU/ha.

Fast, P.G. 1983. *Bacillus thuringiensis* parasporal toxin: aspects of chemistry and mode of action. Toxicon. suppl. 3, pp. 123-125.

Hulme, M.A.; Ennis, T.J.; Lavallée, A. 1983. Current status of *Bacillus thuringiensis* for spruce budworm control. The Forestry Chronicle, April 1983, 58-61.

Research and development over many years have now established that Bacillus thuringiensis Berliner (B.t.) can be a safe and effective biological insecticide for spruce budworm. B.t. must be ingested before it can kill the insect and good results are thus obtained when the B.t. spray is applied at the correct time and covers the foliage so that most larvae consume a lethal dose of B.t. within 1 or 2 days of application. Under these conditions, B.t. treatments can save as much foliage as chemical insecticide treatments. However, the cost of materials and application for a B.t. treatment is higher than for a chemical treatment. In recent years emphasis in B.t. research has thus been to reduce cost by obtaining better distribution of the material on foliage, by reducing the volume of liquid carrier, and by looking for strains and fermentations of B.t. that provide an even more potent product against spruce budworm.

Morris, O.N.; Moore, A. 1983. Relative potencies of 50 isolates of *Bacillus thuringiensis* for larvae of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 115:815-822.

Fifty Bacillus thuringiensis (B.t.) isolates representing K-1, galleriae, K-73, thuringiensis, aizawai, dendrolimus, tolworthi, kenyae, darmstadiensis, alesti, and entomocidus crystal antigen types were bioassayed against fifth-instar spruce budworm, Choristoneura fumiferana (Clem.) larvae. In addition, larvae reared on diet with and

without aureomycin were tested for their susceptiblity to B.t. The data indicated no significant differences in susceptibility to B.t. among insects reared on aureomycin or on aureomycin-free diet, differences were evident in larval growth and mortality among untreated controls. None of the 50 isolates bioassayed was any more toxic to the budworm than is the strain used at present in commercial preparations of B. thuringiensis.

Morris, O.N.; Moore, A. 1983. Changes in spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae), biomass in stands treated with commercial *Bacillus thuringiensis* var. *Kurstaki*. Can. Entomol. 115:431-434.

Larval biomass of the spruce budworm, Choristoneura fumiferana (Clem.), in balsam fir, Abies balsamea L., stands was significantly reduced following aerial applications of commercial Bacillus thuringiensis (B.t.) (Thuricide 16B®, 24B, and 32 BX and Dipel 85)®. Treatment with Dipel vehicle (Dipel 88® without B.t.) did not affect larval biomass. Biomass reduction following the Thuricide treatment was directly related to feeding activity. These findings support published observations on the long-term effect of B.t. on budworm populations.

Percy, J.; Fast, P.G. 1983. *Bacillus thuringiensis* crystal toxin: Ultrastructural studies of its effect on silkworm midgut cells. J. Invert. Pathol. 41: 86-98.

Bacillus thuringiensis crystal toxin induced a cytoplasmic response in columnar cells within 1 min of ingestion although external symptoms were not exhibited by larvae until 15 min after ingestion. Microvilli became less consistently uniform in diameter; their organized internal microfilaments were disrupted and disappeared. The cisternae of rough endoplasmic reticulum were enlarged and denuded of ribosomes. By 5 min after ingestion, microvilli of some columnar cells disappeared entirely and gross ultrastructural changes were observed in other regions of the cells. Up to 5 min after ingestion there were few, if any, ultrastructural changes observed within goblet cells. Mitochondria in columnar cells were swollen but did not exhibit the condensed configuration reported by other workers. Both the buffer system used in the fixation medium and its osmolarity influenced the changes in the ultrastructure of midgut cells exposed to B. thuringiensis crystal toxin.

BIOLOGICAL CONTROL AGENTS: FUNGAL PATHOGENS

Payandeh, B.; MacLeod, D.M.; Wallace, D.R. 1978. Germination of *Entomophthora aphidis* resting spores under constant temperatures. Can. J. Bot. 56(19): 2328-2333.

Germination tests at a wide range of constant temperatures show that upper and lower thresholds for E. aphidis resting spores are about 3.5 and 20.5°C, respectively. Good germination was obtained over the range 10-22°C with an optimum at about

16.5°C. It is not known if spores exposed to temperatures above the optimum and failing to germinate are inactivated or killed. An empirical model is presented that describes the time-temperature-germination relationships of one test population. A similar modelling approach may be also applied to other spore populations.

Wallace, D.R.; MacLeod, D.M.; De Lyzer, A.J. 1978. Endogenous light action in germination of *Entomophthora aphidis* resting spores *in vitro*. Can. For. Serv. Bi-mon. Res. Notes 34(4):24-25.

MacLeod, D.M.; Tyrrell, D. 1979. *Entomophthora crustosa* n. sp. as a pathogen of the forest tent caterpillar, *M. disstria* (Lepidoptera: Lasiocampidae). Can. Entomol. 111:1137-1144.

Entomophthora crustosa n. sp. pathogenic for Malacosoma species (principally M. disstria Hbn.), is described. It is characterized in the conidial state by a hymenial coating which, at maturity, forms a crust-like covering, cinnamon brown, over the surface of infected insects, and by conidial size. In the resting spore (zygospore) state the distinguishing attributes are ornamentation of the zygospores and their mode of development. The pathogen grows readily on coagulated egg-yolk media.

The fungus is briefly compared with 10 other closely related Entomophthora species. Entomophthora crustosa seems to be of widespread occurrence in eastern North America.

MacLeod, D.M.; Tyrrell, D.; Soper, R.S. 1979. *Entomophthora canadensis* n. sp., a fungus pathogenic on the woolly pine needle aphid, *Schizolachnus piniradiate*. Can. J. Bot. 57(23): 2663-2672.

Entomophthora canadensis n. sp. is described and illustrated, and its morphological development traced. The new species differs from all other species of the genus, by its distinctively shaped conidia, long-elliptical to nearly cylindrical, average 25.0 µm x 10.0 µm, and its ornamented azygospores, verruculose to lightly rugulose, average 34.0 µm diameter. It is compared with E. aphidis, within which it has been included, and E. sphaerosperma, the species it most closely resembles.

Entomophthora canadensis is currently known only from populations of the aphid Schizolachnus piniradiate, in red pine plantations in Ontario, Canada.

Tyrrell, D.; Peberdy, J.F. 1979. Spontaneous and enzyme-induced protoplasts from *Entomophthora* species. Proc. 5th Internat. Protoplast Symposium. Szeged, Hungary. Akademiae Kiado, Budapest pp 22-234.

A method was developed for the production of protoplasts from Entomophthora virulenta. Yields of up to 5 x 10^6 per mL were obtained using culture filtrates from Trichoderma harzianum grown on media supplemented with E. virulenta cell walls. The

protoplasts were spherical, multinucleate, and readily regenerated to the normal hyphal form in nutrient media, including Grace's insect tissue culture medium. In this respect, they differ from E. egressa protoplasts, which will grow and multiply in the protoplast state in this medium.

MacLeod, D.M.; Tyrrell, D.; Welton, M.A. 1980. Isolation and growth of the grasshopper pathogen, *Entomophthora grylli*. J. Invert. Pathol. 36: 85-89.

Entomophthora grylli was isolated and grown in pure culture in protoplast form. Cultures were obtained by germinating conidia collected from naturally infected adult Carolina grasshoppers, Dissosteira carolina, in Grace's tissue culture medium supplemented with 5% fetal bovine serum and an aqueous extract of grasshopper tissue. Grasshopper extract was not necessary for subsequent growth and subculture of the protoplasts. Healthy adult grasshoppers could be reinfected with the fungus by injection of a protoplast suspension.

Payandeh, B.; Wallace, D.R.; MacLeod, D.M. 1980. An empirical regression function suitable for modelling spore germination subject to temperature threshold. Can. J. Bot. 58(8): 936-941.

Nonlinear regression analysis and least squares approximation techniques were employed to express percent spore germination as a function of time and temperature. Two sets of spore germination data under varying temperatures were used. A seven-parameter nonlinear regression model was found to fit the data equally as well as previously used mixed linear and two-stage nonlinear regression models. The proposed model is very flexible and allows for the expression of temperature threshold effects. In addition to providing a common set of parameters applicable to the full range of temperatures under consideration, such estimated parameters are amenable to biological interpretation.

Harcourt, D.G; Guppy, J.; MacLeod, D.M.; Tyrrell, D. 1981. Alfalfa weevil fungi identified. Great Lakes Entomologist 14:55.

Soper, R.S.; MacLeod, D.M. 1981. Descriptive epizootiology of an aphid mycosis. U.S. Department of Agriculture, Technical Bulletin No. 1632, 17 pp.

The epizootiology of Entomophthora canadensis MacLeod, Tyrrell, & Soper in populations of the woolly pine needle aphid (Schizolachnus piniradiatae [Davidson]) was investigated during a 5-year period in an isolated plantation of red pine (Pinus resinosa Ait.) in northern Ontario. Climatic factors did not limit the spread of the fungus; the major controlling factors were the density of the fungus inoculum and the density and spatial distribution of the host. An epizootic killed nearly 100 percent of the aphids in early October 1964, and in the subsequent 2 years E. canadensis began to spread at lower population densities and continued to spread faster than during 1961-64, probably because the inoculum density was greater after the epizootic.

McNeil, J.; MacLeod, D.M. 1982. Two species of fungus infecting the European skipper *Thymelicus lineola* (Ochs.) (Lepidoptera: Hesperiidae) in Quebec. Can. Ent. 114: 87-88.

Perry, D.F.; Latge, J-P. 1982. Dormancy and germination of *Conidiobolus obscurus* azygospores. Trans. Br. Mycol. Soc. 78(2):221-225.

The breaking of dormancy of Conidiobolus obscurus azygospores is described. Maturation requires at least 3 months incubation at between 3 and 7°C in an atmosphere maintained at a relative humidity superior to 95%, in a humid soil, or in different substrates such as the attapulgite Clarsol BBC. Maximum germination was conserved for up to 10 months at 4°. Spore germination was determined with regard to temperature, humidity, pH, day-length and spore concentration. Germination requires liquid water and has an optimum temperature between 12° and 16°.

Perry, D.F.; Tyrrell, D.; DeLyzer, A. 1982. The mode of germination of *Zoophthora radicans* zygospores. Mycologia 74(4): 549-554.

Dormancy of Zoophthora radicans resting spores was broken by storage at 4°C and 100% r.h. for 4-5 months. Germination began in 2-4 da at 16°C on water agar; maximum germination of 70% was observed after 20 da, either in continuous light or dark. Germination was similar to that previously described for Z. canadensis in that multiple germ conidia were produced. However, during the later stages of germ tube emergence, the epispore became roughened and dehisced, a phenomenon so far unique to Z. radicans among the entomopathogenic Entomophthorales.

Perry, D.F.; Latge, J-P. 1983. The effect of eight fungicides on germination of *Conidiobolus obscurus* resting spores. J. Invert. Pathol. 42:83-86.

Conidiobolus obscurus resting spore germination was greater than 60% after 21 days incubation in 700 ppm concentrations of Rhodiasoufre, Pelt 44, Dithane M-45, Plantvax, and Saprol. No germ tubes were produced under the same treatment with Bavistine, Quin 20, or Benlate at the same dosage. Germination in distilled water was 85%. After only 24 h contact with Quin 20 (700 ppm) followed by a distilled water wash, germination was not reduced. A higher ability to penetrate the spore wall may account for greater fungicide activity. Resting spores were found to be more resistant to certain fungicides than conidia; however, no general rule could be applied.

Tyrrell, D.; Welton, M.A. 1983. Isolation and culture of *Massospora levispora*. Can. For. Serv. Res. Notes 3(1):1.

BIOLOGICAL CONTROL AGENTS: PROTOZOAN PATHOGENS

Wilson, G.G.; Sohi, S.S. 1977. Effect of temperature on healthy and microsporidia-infected continuous cultures of *Malacosoma disstria* hemocytes. Can. J. Zool. 55: 713-717.

The effects of constant temperatures on healthy and Nosema disstriae infected continuous cultures of Malacosoma disstria hemocytes were studied. Healthy cells grew best at 28°C, followed closely by those at 25 and 30°C. They grew very slowly at 20°C. Cell growth was good at 35°C for the first 4 days. If the medium was changed frequently cells could be kept at this temperature for a longer period without any adverse effect on their viability and growth. There were no significant differences in percentage infection and Nosema per cell in the infected cultures kept at 20, 25, 28, and 30°C. However percentage infection and Nosema per cell were greatly reduced after 1 week at 35°C, and eventually the microsporidia disappeared from the cultures kept at this temperature for 28 days. These observations support other reports to the effect that entomopathogenic microsporidia are unlikely to grow in warm-blooded vertebrates because of their high body temperature.

Wilson, G.G. 1977. Effects of the microsporidia *Nosema disstriae* and *Pleistophora schubergi* on the survival of the forest tent caterpillar *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Can. Entomol. 109:1021-1022.

Wilson, G.G. 1977. The effects of feeding microsporidian *(Nosema fumiferanae)* spores to naturally infected spruce budworm *(Choristoneura fumiferana)*. Can. J. Zool. 55: 249-250.

Infection of spruce budworm, Choristoneura fumiferana in nature by Nosema fumiferanae has an adverse effect on the host. Larval and pupal mortality are increased, while female pupal weight, adult longevity, and fecundity are significantly reduced by feeding additional microsporidian spores to naturally infected spruce budworm.

Wilson, G.G. 1977. Observations on the incidence rates of *Nosema fumiferanae* (Microsporidia) in a spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) population. Proc. Entomol. Soc. Ont. 108: 144-145.

Examination of living spruce budworm, Choristoneura fumiferana, collected in the field over a six-year period indicated that infections caused by Nosema fumiferanae increased as the age of the infestation increased. The levels of infection increased from 35.9% in 1973 to 69.0% in 1978.

Wilson, G.G.; Kaupp, W.J. 1977. Application of *Nosema disstriae* and *Pleistophora schubergi* (Microsporida) against the forest tent caterpillar in Ontario. Forest Pest Manage. Inst. Inf. Rept. FPM-X-4, 9 pp.

A combination of two microsporidian parasites, Nosema disstriae (Thom.) and Pleistophora schubergi Zwolfer were tested against the forest tent caterpillar, Malacosoma disstria, in Ontario during the summer of 1977. A packsack-type mist blower was used to apply suspensions of microsporidian spores on individual trembling aspen (Populus tremuloids Michx). An application rate of 1.8 x 10^{11} spores/tree consisting of P. schubergi and N. disstriae significantly increased the incidence of P. schubergi, but not N. disstriae.

Wilson, G.G. 1978. Detrimental effects of feeding *Pleistophora schubergi* (Microsporida) to spruce budworm *(C. fumiferana)* naturally infected with *Nosema fumiferanae*. Can. J. Zool. 56(4-Pt.1):578-580.

Spores of the microsporidian Pleistophora schubergi Zwolfer were fed to spruce budworm, Choristoneura fumiferana (Clem.), naturally infected with Nosema fumiferanae (Thom.). Larval mortality increased while female pupal weight, adult longevity, and fecundity were significantly reduced by feeding P. schubergi spores. High spore concentrations (5 x 10^8 spores) and inoculation as a second-instar larvae produced the most detrimental effects.

Wilson, G.G. 1978. Microsporidian infection in spruce budworm *(Choristoneura fumiferana)* 1 and 2 years after application. Can. For. Serv. Bi-mon. Res. Notes 34:16.

Wilson, G.G.; Burke, J.M. 1978. Microsporidian parasites of *Archips cerasivoranus* (Fitch) in the district of Algoma, Ont. Proc. Entomol. Soc. Ont. 109:84-85.

Examination of specimens of the uglynest caterpillar, Archips cerasivoranus (Fitch) revealed the presence of three species of micropsoridia, Nosema cerasivoranae Thomson, Pleistophora and Thelohania spp. Incidence, spore sizes of these species, and possible relationships to microsporidia in the spruce budworm, Choristoneura fumiferana (Clem.) are reported.

Wilson, G.G. 1979. Effects of *Nosema disstriae* (Microsporida) on the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Proc. Entomol. Soc. Ont. 110:97-100.

Spores of the microsporidium Nosema disstriae were fed to larvae of the forest tent caterpillar, Malacosoma disstria Hubner. The microsporidian adversely affected pupal weights, adult fecundity and longevity.

Wilson, G.G. 1979. The multiplication of Nosema fumiferanae (Microsporida) in spruce budworm reared on three different diets. Can. For. Serv. Bi-Mon. Res. Notes 36:36-37.

Wilson, G.G. 1979. Reduced spore production of *Nosema fumiferanae* (Microsporida) in spruce budworm, *(Choristoneura fumiferana)* reared at elevated temperatures. Can. J. Zool. 57(5): 1167-1168.

Rearing of naturally infected spruce budworm, Choristoneura fumiferana at 23°C resulted in an increase of 0.4 x 10^5 to 315.3 x 10^5 Nosema fumiferanae spores in an 7- to 21-day period. At 30°C, no increase in the number of spores was found in the same period. Removal of the host insect to the lower temperature resulted in re-establishment of spore production.

Wilson, G.G. 1979. Observations on the incidence of *Nosema fumiferanae* (Microporida) in the spruce budworm,*Choristoneura fumiferana* (Lepidoptera: Tortricidae), population. Proc. Entomol. Soc. Ont. 108: 144-145, 1977.

Wilson, G.G.; Sohi, S.S. 1979. Inoculation of spruce budworm cell cultures with the microsporidian, *Nosema whitei*. Forest Pest Manage. Inst. Inf. Rep., FPM-X-24, 5 pp.

Spores of the microsporidium Nosema whitei were successfully primed to germinate in vitro in tissue culture medium, and inoculated into the spruce budworm cell line IPRI-CF-124. The spores could be treated with the disinfectant Zephiran and still germinate, however to prevent premature germination spores had to be taken from living infected larvae. Many of the spores germinated within 5-10 min. after they were introduced into the cell cultures. The sporoplasms were present in the medium for up to 8 days, and in a few cases some of the germinated spores appeared to be phagocytosed by the cells. However, multiplication of the microsporidium in the cells was not observed. Although this cell line did not get infected with N. whitei it is possible others might.

Wilson, G.G. 1980. Effects of *Nosema disstriae* (Microsporida) on the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Proc. Entomol. Soc. Ont. 110: 97-99.

Wilson, G.G. 1980. Effects of *Nosema fumiferanae* (Microsporida) on rearing stock of spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Proc. Entomol. Soc. Ont. 111: 115-116.

Wilson, G.G. 1980. *Nosema fumiferanae*, a natural pathogen of a forest pest: potential for pest management. *In* H.D. Burges, ed. Microbial control of pest and plant diseases 1970-1980. Academic Press Inc. Ltd., London.

Wilson, G.G. 1980. Persistence of microsporidia in populations of the spruce budworm and forest tent caterpillar. Forest Pest Manage. Inst. Inf. Rep., FPM-X-39, 5 pp.

This report deals with the persistence of Nosema fumiferanae and Pleistophora schubergi after application against the spruce budworm and a combination of Nosema disstriae and P. schubergi against the forest tent caterpillar. Significantly higher levels of N. fumiferanae persisted for about three years in populations of the spruce budworm and forest tent caterpillar when compared to the Nosema sp., however there was no carry-over of P. schubergi.

Wilson, G.G. 1981. The potential of *Pleistophora schubergi* in microbial control of forest insects. Forest Pest Manage. Inst. Inf. Rep., FPM-X-49, 7 pp.

Laboratory and field studies of various researchers have shown that Pleistophora schubergi Zwolfer may have potential as a microbial control agent for several forest insect defoliators in the orders Lepidoptera and Hymenoptera.

In general, P. schubergi is highly effective in killing many insects under laboratory conditions. For example, dosages as low as 10^4 spores/larvae fed to fourth-instar Anistoa senatoria result in 90% mortality. All Malacosoma disstria will die when second-instar larvae are treated with suspensions of 5 x 10^3 P. schubergi spores/mL. Sublethal effects of the microsporidian include smaller larvae displaying less vigor, malformed pupae, and adults which are unable to copulate and lay eggs. Infection rates after field application of P. schubergi have ranged from 40% in Pristiphora erichsonii, 96% in Choristoneura fumiferana to 100% in Symmerista canicosta. Research indicates that this microsporidium is adversely affected by UV radiation and hence the type of formulations used in application will be important. P. schubergi will infect relatively large host insects, which facilitates mass propagation.

Wilson, G.G. 1981. Susceptibility of the larch sawfly to *Pleistophora schubergi* (Microsporida). Can. For. Serv. Res. Notes 1: 1.

Wilson, G.G. 1982. Effects of *Pleistophora schubergi* (Microsporida) on the spruce budworm *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 114: 81-82.

Spores of the microsporidium Pleistophora schubergi were fed to second- and fifth-instar larvae of the spruce budworm, Choristoneura fumiferana. A treatment of 2 x 10^8 spores applied to the surface of the host's diet resulted in 100% mortality to second, and 60% to fifth-instar larvae. Susceptibility of the host to the parasite decreased as the larvae became older. Other effects on host development were not significant at the dosages tested.

Percy, J.; Wilson, G.G.; Burke, J. 1982. Development and ultrastructure of a microsporidian parasite in midgut cells of the larch sawfly *Pristiphora erichsonii* (Hymenoptera: Tenthredinidae). J. Invert. Pathol. 39: 49-59.

The development stages of a microsporidium from larvae of Pristiphora erichsonii were investigated. Meronts appeared to be the only stage containing a diplokaryon. Nuclei of sporonts in a parasitophorous vesicle underwent at least three divisions and uni-nucleate sporoblasts developed from these multi-nucleate sporonts. As many as 38 spores were observed with a vesicle. A thin pansporoblastic membrane limited the vesicle and was derived from rough endoplasmic reticulum of the host cell. The microsporidium was tentatively identified as Pleistophora sp. Infection levels of the microsporidium in natural populations of P. erichsonii reached 25%.

Wilson, G.G. 1982. Protozoans for insect control *In* E. Kurstak, ed. Microbial and Viral Pesticides. Marcel Dekker Inc., New York, N.Y.

Wilson, G.G. 1982. Transmission of *Nosema fumiferana* (Microsporidia) to its host *Choristoneura fumiferana* (Clem.). Z. Parasitenkd. 68: 47-51.

Nosema fumiferanae may be transmitted perorally, transovarially, or by injection into its host Choristoneura fumiferana. Infected females, but not infected males, readily transmit the parasite to their offspring. Ingestion of diet, surface treated with 10^5 N. fumiferanae spores per 7.0 cm^2, resulted in sublethal infection in adults, and reduced the number of hatchable eggs by 19%.

BIOLOGICAL CONTROL AGENTS: VIRAL PATHOGENS

Ilnytzky, S.; Cunningham, J.C.; McPhee, J.R. 1977. Comparison of field propagated nuclear polyhedrosis virus from Douglas-fir tussock moth with laboratory produced virus. Can. For. Serv. Bi-Monthly Res. Notes 33:5-6.

Steltzer, M.; Neisess, J.; Cunningham, J.C.; McPhee, J.R. 1977. Field evaluation of baculovirus stocks against Douglas-fir tussock moth in British Columbia. J. Econ. Entomol. 70:243-245.

Aerial applications of 3 baculovirus stocks were tested against Orgyia pseudotsugata (McDunnough) in British Columbia in June 1975. A dosage of 100 billion polyhedra/acre, formulated in a molasses and nonmolasses formulation and applied at 1 or 2 gal/acre, provided population control and excellent foliage protection. Larvae collected from the treated areas 5 days after spraying showed virus infection rates that ranged from 60-87%. With the exception of one treatment that was applied under extremely adverse meteorological conditions there were no significant differences between virus treatments. Population densities were reduced by more than 90% at 21 days post-treatment, and no evidence of survival to the pupal stage was found on the virus-treated areas.

Arif, B.M. 1978. Biochemical investigations on a nuclear polyherosis virus of the spruce budworm. Forest Pest Manage. Inst. Inf. Rep., FPM-X-10. 25 pp.

A nuclear polyhedrosis virus from the spruce budworm, Choristoneura fumiferana, was purified and its genome was extracted by several procedures. Examination of the DNA by methylated albumin kieselguhr chromatography demonstrated that it elutes as a single homogeneous band at 0.75 M NaCl. On CsCl gradients, the genome bands at a density of 1.7075 g/mL. However, analysis on CsCl gradients containing 125 µg/mL of ethidium bromide revealed the presence of two fluorescent bands of closed circular (ρ = 1.633 g/mL) and relaxed (ρ = 1.593 µg/mL) DNA molecules. On neutral sucrose gradients the viral DNA was resolved into one component with sedimentation coefficients of 46.25. The molecular weight of the genome was calculated to be 61.0 - 68.3 x 10^6 daltons when analyzed with respect to the DNA of bacteriophage T2. The GC content of the viral genome (48.4%) was computed from the values of two DNA standards from E. coli and Cl. perfringens in heat denaturation experiments in 0.1 x SSC.

Arif, B.M.; Dobos, P. 1978. Studies on the effect of a nuclear polyhedrosis virus of the spruce budworm on the replication of vertebrate viruses in mammalian, avian, and fish cell lines. Forest Pest Manage. Inst. Inf. Rep., FPM-X-14, 12 pp.

Virus interference tests were carried out using cells of mammalian, avian, or fish origin. The cells were inoculated with nuclear polyhedrosis virus (NPV) and challenged with a virus that is known to replicate and to produce a cytopathogenic effect (e.g., chick embryo fibroblast cells with Sindbis virus, L cells with Encephalomyocarditis virus, RTG-2 and FHM fish cells with infectious pancreatic necrosis virus). When cell destruction was evident, the progeny vertebrate virus was assayed and its titre was compared to that of virus produced in cells not inoculated with NPV. The results showed that NPV did not interfere with the replication of other viruses in vertebrate cell lines.

Cunningham, J.C.; Kaupp, W.J.; Howse, G.M.; McPhee, J.R.; de Groot, P. 1978. Aerial application of spruce budworm baculovirus: tests of virus strains, dosages and formulations in 1977. Forest Pest Manage. Inst. Inf. Rep. FPM-X-3, 37 pp.

Five plots with a total area of 148 ha were treated with spruce budworm, Choristoneura fumiferana, nuclear polyhedrosis virus to test 3 formulations, 2 dosages and 2 strains of virus. The application was made with Gruman Agcat equipped with boom and nozzle spray equipment calibrated to deliver 9.4 L/ha. Larvae were mainly in the fourth- and fifth-instar in 4 of the plots and fifth-instar with some sixth instar present in the other plot. The efficacy of the treatment was assessed by 5 methods. Generally the results indicated that a formulation containing 250 mL/L molasses, 60 g/L IMC 90-001 UV protectant and 1.25 mL/L Chevron sticker was superior to a polymer bound carbon formulation or a virus adjuvant manufactured by Sandoz Inc., SAN 285 wettable powder. Subsequent laboratory tests showed that considerable inactivation of the virus had occurred as a result of preparing the polymer bound carbon formulation. The SAN 285 wettable powder was compatible with the virus. The effic-

acy of virus isolates obtained from Choristoneura fumiferana and C. occidentalis were similar. When two dosages of the C. fumiferana nuclear polyhedrosis virus were compared, 750 billion polyhedra/ha gave considerably better results than 250 billion. The former dosage gave a population reduction of 92% which is the best result obtained to date with a nuclear polyhderosis virus treatment on spruce budworm.

Kaupp, W.J.; Cunningham, J.C.; Howse, G.M.; McPhee, J.R.; de Groot; P. 1978. Aerial application of spruce budworm baculovirus: tests on second instar larvae in 1976. Forest Pest Manage. Inst. Inf. Rep. FPM-X-2, 20 pp.

Three plots, containing mainly white spruce, Picea glauca (Moench) Voss, with a total area of 120 ha, were sprayed with a nuclear polyhedrosis virus when larvae of the spruce budworm, Choristoneura fumiferana (Clem.), were in the needle-mining second-instar. Aerial applications were made at 9.4 L/ha with a virus dosage of 125 billion polyhedra/ha. The aqueous formulation contained 250 mL/L molasses, 60 g/L IMC 90-001 sunlight protectant and 1.25 mL/L Chevron sticker. Two of the plots received a second application 6 days later with the same dosage and formulation.

Levels of virus infection and subsequent mortality were lower than those recorded following virus application on later instars in previous years. The double application gave better larval infection than the single but was still unsatisfactory. It is concluded that the second instar, although highly susceptible to nuclear polyhedrosis virus, is not the best stage of insect development for virus application with the formulation currently available.

Kaupp, W.J.; Cunningham, J.C.; de Groot; P. 1978. Aerial application of baculovirus on redheaded pine sawfly, *Neodiprion lecontei* (Fitch) in 1977. Forest Pest Manage. Inst. Inf. Rep. FPM-X-1, 31 pp.

Two red pine, Pinus resinosa Ait., plantations near Renfrew, Ontario, and one jack pine, Pinus banksiana Lamb., plantation south of Ottawa, Ontario, with a combined area of 48 ha and infested with redheaded pine sawfly were aerially sprayed with nuclear polyhedrosis virus. Larvae were predominantly in the second- and third-instar in the red pine plantations and in the fourth-instar in the jack pine plantation at the time of application. A dosage of 5.5 billion polyhedra/ha was applied at 9.4 L/ha in an aqueous formulation containing 25 mL/L molasses and 60 g/L IMC 90-001 sunlight protectant. The level of virus infection and reduction in number of sawfly colonies were monitored and excellent control was achieved. In one locality, the virus spread to an adjoining, infested 8 ha plantation and killed the sawfly larvae. Damage to the trees in all three treated areas was slight and no trees suffered terminal shoot defoliation.

Arif, B.M.; Dobos, P. 1979. Effect of a nuclear polyhedrosis virus of the spruce budworm on the metabolic process of vertebrate cells. Forest Pest Manage. Inst. Inf. Rep. FPM-X-15, 16 pp.

Mouse, fish, and bird cell cultures were inoculated with a nuclear polyhedrosis virus of the spruce budworm, Choristoneura fumiferana, and at one, two or three days after inoculation radioactive uridine, thymidine or leucine was added. At 2-h intervals thereafter, the cells were processed and the synthesis of RNA, DNA or protein was determined. The results, compared to those from mock infected cells, were presented as qualitative incorporation of the radioactive precursor into the respective macromolecule. The data showed that the synthesis of RNA, DNA or protein increases linearly with time and there was no difference between infected and mock infected cells observed.

Cunningham, J.C.; Howse, G.M.; McPhee, J.R.; de Groot, P.; White, M.B.E. 1979. Aerial application of spruce budworm baculovirus: replicated tests with an aqueous formulation and a trial using an oil formulation in 1979. Forest Pest Manage. Inst. Inf. Rep. FPM-X-21, 19 pp.

Six 20-ha plots and one 14-ha plot, located north of Thessalon, Ontario, containing predominantly white spruce trees, Picea glauca (Moench) Voss, with some balsam fir, Abies balsamea (L.) Mill., were aerially sprayed with nuclear polyhedrosis virus to control spruce budworm, Choristoneura fumiferana (Clem.). Larvae were mainly in the fifth- and sixth-instars at the time of application. A dosage of 750 billion polyhedral inclusion bodies/ha was applied with boom and nozzle spray equipment on all plots in an emitted volume of 9.4 L/ha. Six of the plots were treated with an aqueous formulation containing 250 mL/L molasses, 250 mL/L Sandoz Shade and 0.5 mL/L Triton B-1956 spreader-sticker. The seventh plot was treated with an emulsifiable oil formulation containing 650 mL/L Sunoco Sunspray 11E oil and 350 mL/L water, with Rhodamine B dye as a tracer.

The population reduction of spruce budworm larvae due to the treatment was monitored on white spruce hosts in all 7 plots and on balsam fir in 4 plots. In the 6 plots treated with the aqueous formulation, population reduction due to treatment ranged from 33% to 92% and in the 3 plots where balsam fir hosts were studied, population reduction ranged from 37% to 76%. In the plot sprayed with the emulsifiable oil formulation, population reduction was 33% on white spruce hosts and 41% on balsam fir. As larval development was more advanced in this plot with 82% in the sixth instar, these lower population reduction figures do not necessarily mean that the oil formulation was inferior to the aqueous.

de Groot, P.; Cunningham, J.C.; McPhee, J.R. 1979. Control of red-headed pine sawfly with a baculovirus in Ontario in 1978 and a survey of areas treated in previous years. Forest Pest Manage. Inst. Inf. Rep. FPM-X-20, 14 pp.

An aerial spray trial was conducted with redheaded pine sawfly nuclear polyhedrosis virus near Sharbot Lake, Ontario in 1978. Two red pine, Pinus resinosa Ait., plantations with a total area of 26.1 ha, infested with redheaded pine sawfly, Neodiprion lecontei (Fitch), were sprayed with a dosage of 5 billion polyhedra/ha at a rate of 9.4 L/ha in an aqueous formulation containing 135 mL/L molasses and 32 g/L molasses and 32 g/L Sandoz Shade when larvae were predominantly in the second-instar. Over

90% of the sawfly colonies were diseased or dead 16 days after the application and after 23 days no healthy colonies remained. Defoliation was lighter in the treated areas compared to untreated check plots.

Bilmoria, S.L.; Arif, B.M. 1979. Subunit protein and alkaline protease of entomopoxvirus spheroids. Virology 96: 596-603.

The inclusion body (spheroid) matrix of Choristoneura biennis (Free.) entomopoxvirus is composed of a single subunit protein termed spheroidin. This protein has a molecular weight of 102,000 when extracted by detergent disruption of spheroids in 8 M urea. These conditions inhibit an alkaline protease activity which we have detected in the spheroids. The enzyme has an optimum pH range of 10 to 11. It is heat labile, in that 90% of the activity is destroyed by heating at 60° for 10 min. and is inhibited by soybean trypsin inhibitor, sodium dodecyl sulfate and mercuric ion. Activation of the protease during extraction by alakaline dissolution of the spheroids or by detergent disruption in the absence of 8 M urea results in the breakdown of the spheroidin subunit into discreet peptides.

Hodgkinson, R.S.; Finnis, M.; Sheperd, R.F.; Cunningham, J.C. 1979. Aerial applications of nuclear polyhedrosis virus and *Bacillus thuringiensis* against western spruce budworm. Joint B.C. For. Serv. & Can. For. Serv. Report No. 10, 19 pp.

Bilmoria, S.L.; Arif, B.M. 1980. Structural polypeptides of *Choristoneura biennis* entomopoxvirus. Virology 104(1):253-257.

The structural polypeptides of Choristoneura biennis (Free) entomopoxvirus (EPV) were analyzed. The virion contained at least 40 polypeptides ranging from 12,000 to 250,000 in molecular weight. Twelve major proteins constitute 95% of the total virus protein. Core particles generated by treatment with Nonidet P-40, under conditions during which endogenous alkaline protease is active, display a smooth exterior similar to those obtained for orthopoxviruses. The major component of these cores is a polypeptide with a molecular weight of 59,000.

Burke, J.M. 1980. A survey of micro-organisms infecting a spruce budworm population. Forest Pest Manage. Inst. Inf. Rep. FPM-X-37, 9 pp.

The occurrence of microorganisms in developing and declining infestations of the spruce budworm, Choristoneura fumiferana (Clemens), was studied over a seven year period. The microsporidium, Nosema fumiferanae, was the only organism whose incidence in spruce budworm increased as the populations aged. Other microsporidia, Thelohania sp. and Pleistophora sp., as well as a nuclear polyhedrosis virus and several fungi, remained at such low levels as to have little or no impact on the populations. The most interesting organism recovered was an entomopoxvirus infecting a natural population of the spruce budworm. This was the first record of such a virus occurring in the spruce budworm.

Arif, B.M.; Brown, K.W. 1980. Two entomopoxvirus strains isolated from the spruce budworm, Choristoneura fumiferana (Clem.) Can. For. Serv. Bi-mon. Res. Notes 36(1): 1.

Two strains of entomopoxvirus were found in spruce budworm larvae with one strain having much larger inclusion bodies than the other. In mixed infections the two strains did not replicate in the same cell. After serial passage of a mixture of both strains in insect larvae, the strain with larger inclusion bodies was eventually eliminated and it is concluded that the smaller strain is the more virulent.

Kaupp, W.J. 1980. A simple method of assessing the quantities of nuclear polyhedrosis virus entering the soil from diseased populations of European pine sawfly. Can. For. Serv. Bi-mon. Res. Notes 36(6):31.

Sand-filled plastic tubs are used to entrap polyhedra inclusion bodies falling from the tree canopy to the ground. Nuclear polyhedrosis virus inclusion bodies are extracted from the sand and quantified using a dry-counting method. Information on the quantities of virus produced and falling to the ground from diseased sawfly populations is presented.

Kaupp, W.J. 1980. Development of the enzyme-linked immunosorbent assay to detect a nuclear polyhedrosis virus in European pine sawfly larvae. Can. For. Serv. Bi-mon. Res. Notes 36(3):10-11.

An immunological method is applied to detect as low as 4×10^5 polyhedral inclusion bodies per infected larvae. It was found easier and more efficient to detect polyhedrin (inclusion body proteins) as an antigen and index of viral infection than virus particle antigen. This method has the potential of increasing the efficiency of viral diagnosis of insect specimens as well as being adaptable for detection of virus infection in other insect species.

Ives, W.G.H.; Cunningham, J.C. 1980. Application of nuclear polyhedrosis virus to control Bruce spanworm (Lepidoptera: Geometridae). Can. Entomol. 112:741-744.

Ground spray trials were conducted with a nuclear polyhedrosis virus to control Bruce spanworm in Alberta in 1979. Three virus dosages and two application times were tested, (on first instar larvae and on second- and third-instar larvae). The assessment was confused by the presence of a naturally occurring virus disease. Some foliage protection was achieved with the artificially disseminated virus, but none with the naturally occurring virus. However, the cost of producing Bruce spanworm nuclear polyhedrosis virus in its homologous insect host precludes its use as a biocontrol agent until a larger insect host is found for virus propagation.

Morris, O.N. 1980. Entomopathogenic viruses: strategies for use in forest insect pest management. Can. Entomol. 112:573-584.

Strategies for the use of entomopathogenic viruses in the management of forest insect pests include the use of viruses by themselves or with other biocontrol or chemical agents applied simultaneously or separately at strategic time intervals. It is concluded that baculoviruses (nuclear polyhedrosis and granulosis viruses) have considerable potential as components of integrated forest insect pest management systems. The prime limiting factors in their large scale use at present are the high cost of virus production and underdevelopment of applications technology. Their greatest potential will probably be realized when used as an indirect, or preventative, strategy with a view to preventing the occurrence of pest emergency situations.

Cunningham, J.C. 1981. Book review: Microbial Control of Insect Pests. (J. Kalmakoff and J.F. Longworth, Comp.) New Zealand D.S.I.R. Bull. Entomol. Soc. Canada 13(3):94-95.

Cunningham, J.C.; Entwhistle, P.F. 1981. Control of sawflies by baculovirus. pages 379-497 *In* H.D. Burges, ed. Microbial Control of Pests and Plant Diseases 1970-1980 Academic Press, New York, N.Y.

This book chapter contains a review of the following topics:

I. Sawflies and their Baculoviruses
- *A. Sawflies as Pests*
- *B. Sawfly Baculoviruses*
- *C. Sawfly Virus Ecology in Relation to Control*
- *D. Biology of Sawflies in Relation to Control by Viruses*

II. Laboratory Assessment of Baculoviruses
- *A. Diagnostic Methods*
- *B. Pathogenicity Tests*

III. Production of Sawfly Baculoviruses
- *A. Production in Laboratory and in Plantations*
- *B. Commercial Production*
- *C. Purification Methods*

IV. Characterization and Safety Testing
- *A. Biochemical Characterization*
- *B. Safety Testing*

V. Control - Examples and Methods
- *A. Introduction*
- *B. Examples*
- *C. Discussion of Application Methods*

VI. Assessment of the Value of Baculoviruses for Sawfly Control.

VII. References

Cunningham, J.C.; Tonks, N.V.; Kaupp, W.J. 1981. Viruses to control winter moth, *Operophtera brumata* (Lepidoptera: Geometridae). J. Entomol. Soc. B.C. 78:17-24.

An abandoned apple orchard in Victoria, British Columbia, was used to test winter moth nuclear polyhedrosis virus (NPV) in 1979. Concentrations of 10^8, 10^7 and 10^6 polyhedral inclusion bodies (PIB)/mL were applied at the rate of 1 L/tree using a backpack mistblower, soon after the larvae hatched when buds were pre-pink and 8 days later when the buds were full pink. Each treatment was replicated on 6 trees; 6 trees were untreated checks. Best results were with 10^8 PIB/mL on pre-pink buds which caused 46% population reduction, a statistically significant saving of foliage and high levels of larval infection with both NPV and cytoplasmic polyhedrosis virus (CPV). Both viruses were found in larvae on the check trees and this was attributed to spray drift. The source of the CPV was investigated and found to be a contaminant of the NPV suspension in which the ratio of NPV:CPV PIB was 161:1. Despite the low level of CPV applied, up to 65% of the larvae were infected. In 1980, a survey to determine levels of infection in winter moth larvae showed no viruses in 5 untreated sites and only 1% NPV and 5% CPV in the treated orchard. The virus treatment did not initiate a continuing epizootic and the effective concentration of 10^8 PIB/mL was too costly to produce as a biocontrol agent having an impact only in the season of application.

Hicks, B.D.; Geraci, J.R.; Cunningham, J.C.; Arif, B.M. 1981. Effects of redheaded pine sawfly, *Neodiprion lecontei*, nuclear polyhedrosis virus on rainbow trout, *Salmo gairdneri*, and *Daphnia pulex*. J. Environ. Sci. Health B16(4):492-509.

The effects of a nuclear polyhedrosis virus (NPV) of the red-headed pine sawfly, Neodiprion lecontei, on rainbow trout, Salmo gairdneri, were investigated. The fish were exposed to this virus by intubation and topical application and no ill-effects were observed. Similarly, no ill-effects were detected in Daphnia pulex when the same NPV was added to their culture medium. The materials were lyophilized, NPV-infected sawfly larvae (normally used for insect control), lyophilized, uninfected larvae and purified, polyhedral inclusion bodies. On the basis of these laboratory tests, this virus, when disseminated as a biocontrol agent, should present no hazard to rainbow trout or to the aquatic invertebrate Daphnia pulex, two species frequently used in toxicity tests of chemical pesticides.

Sohi, S.S.; Percy, J.; Cunningham, J.C.; Arif, B.M. 1981. Replication and serial passage of a multicapsid nuclear polyhedrosis virus of *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae) in continuous insect cell lines. Can. J. Microbiol., 27:1133-1139.

A multicapsid nuclear polyhedrosis virus (MNPV) of the Douglas-fir tussock moth, Orgyia pseudotsugata, propagated in larvae of the white-marked tussock moth, O. leucostigma, was successfully grown in two continuous cell lines developed from minced neonate larvae of O. leucostigma. Polyhedral inclusion bodies (PIBs) appeared in the nuclei of cells within 24 h after inoculation. Cytopathological changes, as revealed by light and electron microscopy, were typical of an MNPV. The virus has been passaged in the cell cultures 55 times. The level of infection during passaging has varied from 15 to 98% of the cells, and the number of PIBs per cell from 10 to 40. The PIBs from the fourth passage of the virus in cell cultures were almost as pathogenic to O. leucostigma larvae as the PIBs produced in larvae.

Burke, J.M.; Percy, J. 1982. Survey of pathogens in the large aspen tortrix *Choristoneura conflictana* Wlk. (Lepidoptera: Tortricidae), in Ontario and British Columbia with particular reference to granulosis virus. Can. Entomol. 114:457-459.

This is a report on the occurrence of granulosis virus, entomopoxvirus, microsporidia and Entomophthora sp., alone, and in combination with each other, in populations of the large aspen tortrix in Ontario and British Columbia. Particular reference is made to the granulosis virus, and its ultrastructural characteristics.

Cunningham, J.C. 1982. Field Trials with Baculoviruses: Control of Forest Insect Pests. pages 335-386 *In* E. Kurstak, ed. Microbial and Viral Pesticides. Marcel Dekker, New York, N.Y.

Kaupp, W.J. 1982. A paper-cup container for the bioassay of nuclear polyhedrosis virus on foliage. Can. For. Serv. Research Notes 2(4):23.

Shapiro, M.; Martignoni, M.E.; Cunningham, J.C.; Goodwin, R.H. 1982. Potential use of the saltmarsh caterpillar as a production host for nucleopolyhedrosis viruses. J Econ. Entomol. 75:69-71.

The virulence of the nucleopolyhedrosis viruses (NPVs) of Douglas fir-tussock moth, Orgyia pseudotsugata (McDunnough), spruce budworm, Choristoneura fumiferana (Clemens), and gypsy moth, Lymantria dispar (L.), for larvae of the saltmarsh caterpillar, Estigmene acrea (Drury), was enhanced after successive passage in the alternate host. In all cases, yields of 2 x 10^9 polyhedral inclusion bodies were obtained and C. fumiferana NPVs obtained from the respective natural hosts. The O. pseudotsugata-NPV-E. acrea system appears to be an excellent system for production of Douglas-fir tussock moth NPV on the basis of both virus yield and activity. The C. fumiferana NPV-E-acrea and L. dispar NPV-E. acrea systems appear less promising on the basis of virus activity.

Sheperd, R.F.; Gray, T.G.; Cunningham, J.C. 1982. Effects of nuclear polyhedrosis and *Bacillus thuringiensis* on western spruce budworm, (Lepidoptera: Tortricidae) 1 and 2 years after aerial application. Can. Entomol. 114:281-282.

Burke, J.; Percy, J. 1983. Viruses infecting five species of lepidoptera. Can. For. Serv. Res. Notes. 3(1):1-2.

Viruses identified by electron microscopic preparations from field-collected insects included MPNV in Cingilia catenaria (Geometridae), CPV in Thera juniperata (Geometridae), GV in Hydria prunivorata (Geometridae), GV in Archippus packardianus (Tortricidae), GV in Rhyacionia buoliana (Olethreutridae).

Cunningham, J.C.; Kaupp, W.J.; McPhee, J.R. 1983. A comparison of the pathogenicity of two baculoviruses to the spruce budworm and the western spruce budworm. Can. For. Serv. Res. Notes 3(2):9-10.

Cunningham, J.C.; Kaupp, W.J.; McPhee, J.R.; Shepherd, R.F. 1983. Ground spray trials with two baculoviruses on western spruce budworm. Can. For. Serv. Res. Notes 3(2):10-11.

Kaupp, W.J. 1983. Persistence of *Neodiprion sertifer* (Hymenoptera: Diprionidae) nuclear polyhedrosis virus on *Pinus contorta* foliage. Can. Entomol. 115:869-873.

The persistence of Neodiprion sertifer nuclear polyhedrosis virus (NPV) on Pinus contorta foliage samples collected from sawfly infested plantations located throughout Britain was studied. Sawfly density and disease epizootiology varied between localities. Results from the bioassay of branch samples, divided into bark, needle base and foliage samples, indicated that N. sertifier NPV produced during a single virus epizootic can persist for at least 2 years on the pine foliage. Bark and needle base samples were found to be contaminated with NPV more often than foliage samples, perhaps reflecting the effect of weathering on the persistence of virus on the needle surface.

Percy, J.; Cunningham, J.C.; Burke, J.M.; Otvos, I.S. 1983. Two viruses from western false hemlock looper, *Nepytia freemani* (Lepidoptera: Geometridae). Can. Entomol. 115: 1239-1241.

Tissue obtained from field-collected insects and prepared for elecron microscopy is shown to contain an NPV of the multicapsid and a cytoplasmic polyhedrosis virus (CPV). Two sizes of CPV inclusion bodies were observed, one very large, ranging in diameter from 6 µm to 14 µm and the other much smaller having a mean diameter of 1 µm. Both contained spherical virus particles typical of those found in CPV inclusion bodies. The significance of the abnormally large inclusion bodies is not known. Although cells were usually infected either with NPV or with CPV, both types of virus were observed in a few midgut columnar cells.

de Groot, P.; Cunningham, J.C. 1983. Aerial spray trials with a baculovirus to control redheaded pine sawfly in Ontario in 1979 and 1980. Forest Pest Manage. Inst. Inf. Rep. FPM-X-63, 12 pp.

Aerial spray trials were conducted in 1979 to compare the efficacy of a redheaded pine sawfly baculovirus suspension formulated in water, molasses and Sandoz Shade® with a suspension in water alone. In 1980, trials were conducted to compare the efficacy of the same virus dosage emitted at three application rates: 2.35, 4.70 and 9.40 L/ha. Also, in 1980, a comparison was made between the standard, lyophilized, virus-infected insect preparation and a purified virus suspension. The same virus dosage, 5 x 10^9 PIBs/ha, was used in all three tests.

All treatments resulted in complete insect mortality from virus infection. Based on the results of these studies, it is suggested that a crude virus preparation be formulated in water alone and emitted at 5 x 10^9 PIB/ha in a volume of 2.35 L/ha for control of first- and second-instar redheaded pine sawfly larvae. Additional studies on lowest effective application rate and dosage, as well as further replication of the current recommendations, are advocated.

BIOLOGICAL INTERACTIONS: INSECT PATHOGENS IN VITRO

Bilmoria, S.L.; Sohi, S.S. 1977. Development of an attached strain from a continuous insect cell line. In Vitro 13:461-466.

Sohi, S.S.; Wilson, G.G. 1979. Effect of antimicrosporidial and antibacterial drugs on *Nosema disstriae* (Microsporida) infection in *Malacosoma disstria* (Lepidoptera: Lasiocampidae) cell cultures. Can. J. Zool. 57: 1222-1225.

Continuous hemocyte cultures (IPRI-MD-66) established from Malacosoma disstria (Lepidoptera: Lasiocampidae) and persistently infected with Nosema disstria were treated separately with two antimicrosporidian drugs, fumagillin and benomyl, and an antibacterial drug, gentamicin. Treatment with fumagillin (2.5 and 10 µg/mL) or benomyl (25 µg/mL) for 35 days permanently eliminated the microsporidium without adversely affecting the host cells. The use of benomyl for 7 days considerably reduced infection, but infection levels increased to that of the untreated controls when the drug treatment was discontinued. Gentamicin (50 and 100 µg/mL) used for 35 days had no adverse effect on Nosema or the host cell.

Sohi, S.S. 1979. Hemocyte cultures and insect hemocytology. Pages 259-277 *In* A.P. Gutpa, ed. Insect Hemocytes: Development, forms, functions & techniques. Cambridge University Press, Cambridge, U.K.

Sohi, S.S. 1980. The effect of pH and osmotic pressure on the growth and survival of three lepidopteran cell lines. Pages 35-43 *In* K. Kurstak, K. Maramorosch & A. Dubendorfer, eds., Invertebrate Systems in Vitro. Elsevier/North Holland Biomedical Press, Amsterdam.

When cell lines of C. fumiferana (IPRI-CF-124), O. leucostigma (IPRI-OL-13) and M. sexta (FPMI-MS-12) were grown in medium with pHs ranging from 5.0 to 8.0 and at osmolalities from 200 to 488mOsm/kg, all three cell lines grew best within a prefiltration pH range of 6.0-6.5 which produced a pH range of 6.2-6.8 after the medium was filtered and 15% FBS was added. There was very little growth at prefiltration pH 5.0 and 7.5, and all the cells died at pH 8.0. The range of tolerance of all three cell lines for variation in osmotic pressure was quite wide. They grew almost equally

well at 300-400mOsm/kg, and for IPRI-OL-13 cells this tolerance range was even wider. The optimum pH and osmotic pressure for the growth and survival of lepidopteran cell cultures appear to be close to the pH and osmotic pressure of their larval hemolymph as expected.

Sohi, S.S.; Ennis, T.J. 1981. Chromosomal characterization of cell lines of *Neodiprion lecontei* (Hymenoptera: Diprionidae). Proc. Entomol. Soc. Ont. 112:45-48.

Gole, J.W.D.; Downer, R.G.H.; Sohi, S.S. 1982. Octopamine-sensitive adenylate cyclase in haemocytes of the forest tent caterpillar, *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae). Can. J. Zool. 60:825-829.

Injection of octopamine into the haemocoel of third instar larvae and pupae of the forest tent caterpillar, Malacosoma disstria, results in a rapid elevation of haemolymph cyclic AMP levels. The elevated cyclic AMP levels are due, at least in part, to the action of octopamine on haemocytes, as evidenced by the octopamine-induced stimulation of adenylate cyclase in an established haemocyte cell line (Md 66). The effect is simulated by the adrenergic agonist, synephrine, and inhibited by the α-adrenergic blocking agent, phentolamine. The insect haemocyte receptor-enzyme system resembles equivalent vertebrate systems in being activated by sodium fluoride and requiring GTP for expression of effector-induced activation of the enzyme.

BIOLOGICAL INTERACTIONS: CELLULAR INTERACTIONS

Weatherston, J.; Percy, J. 1977. Pheromones of male lepidoptera. Pages 295-307. *In* K.G. Adiyodi & R.C. Adiyodi, eds. Advances in Invertebrate Reproduction. Vol. 1, Peralam-Kenoth, Kerala, India.

An invited review of the structure of glands producing pheromones in male Lepidoptera, the chemistry of the secretion and biosynthetics of these products.

Weatherston, J.; Percy, J.E. 1978. Venoms of Coleoptera. *In* S. Bettini, ed. Handbook of Experimental Pharmacology, vol. 48 Arthropod Venoms, Springer-Verlag, New York, N.Y.

An invited review of the morphology and histology of defensive glands in this order, and the chemistry and function of their secretions.

Weatherston, J.; Percy, J.E. 1978. Venoms of Thyncota (Hemiptera). *In* S. Bettini, ed. Handbook of Experimental Pharmacology. vol. 48 Arthropod Venoms, Springer-Verlag.

An invited review of the morphology and histology of defensive glands in this order and the chemistry and function of their secretions.

Percy, J.E.; MacDonald, J.A. 1979. Cells of the thoracic defensive gland of the redhumped caterpillar, *Schizura concinna* (J.E. Smith) (Lepidoptera: Notodontidae): ultrastructural observations. Can. J. Zool. 57(1):80-94.

The thoracic defensive gland in larvae of Schizura concinna J.E. Smith consists of an anterior and posterior gland joined by an interglandular neck. Ultrastructural observations indicated that there are no cuticular ductules associated with gland cells and that there are three, or possibly four, types of cells within the gland. Two types, as suggested by their location, probably function to maintain the form of the orifice and the interglandular neck. The remaining cells, located in the anterior gland, the anterior lateral longitudinal folds, and the posterior gland exhibit no appreciable ultrastructural differences from each other. Only the cells of the lateral longitudinal folds contain deposits of a lipid-like material. The apical plasma membranes of these cells have a peculiar array of folds surrounding cylinders of endocuticle. Within the apical folds these cylinders are encircled longitudinally by tubules which presumably arise from smooth tubular endoplasmic reticulum. Within the cuticle overlying the cells are filaments which are similar in appearance to the secretion contained within the lumen of the glands.

Weatherston, J.; Percy, J.E.; MacDonald, L.M.; MacDonald, J.A. 1979. Morphology of the prothoracic defensive gland of *Schizura concinna* (J.E. Smith) (Lepidoptera: Notodontidae) and the nature of its secretion. J. Chem. Ecol. 5(2): 165-177.

The larval defensive gland of Schizura concinna (J.E. Smith) is situated in the thorax and consists of two sacs joined by an interglandular neck. Its orifice opens into a transverse invagination of the integument of the cervical margin of the prosternite. The major component of the defensive secretion, formic acid, was identified as its p-bromophenacyl ester. Ancillary components decyl acetate, dodecyl acetate, and 2-tridecanone from the anterior portion of the gland were identified by GLC and GS-MS.

Percy, J.; MacDonald, J.A.; Weatherston, J. 1980. Ultrastructure of scent glands in larvae of *Apateticus bracteatus* (Hemiptera: Pentatomidae) and chemical composition of the secretion. Can. J. Zool. 58: 2105-2115.

The three dorsal abdominal glands in larvae of Apateticus bracteatus (Pentatomidae) secrete a mixture of compounds. Major volatile constituents of the secretion are identified as tridecane and 2-octenal. There are trace amounts of 2-hexenal and two other unidentified compounds.

Each of the glands has paired orifices that are located between tergites 3/4, 4/5, and 5/6, but only the most anterior gland is paired. In anterior glands of mid-instar larvae, glandular cells associated with ducts, and interstitial glandular cells are distributed along the ventral walls of the reservoirs. In posterior glands, columnar glandular cells are located in the anterior dorsal wall of the reservoirs; secretory cells associated with ducts, and nonglandular interstitial

cells are distributed throughout the ventral and posterior walls of the reservoirs. The interstitial glandular cells of the anterior gland and the columnar glandular cells of the middle and posterior glands contain cytoplasmic organelles characteristic of lipid-producing cells. In all glands the secretory cells associated with ducts secrete lipids. Evidence indicating the importance of Golgi and ER in secretion synthesis is presented. The reservoirs and ducts have a thin cuticular lining.

The bearing of the results on present ideas of gland function in Heteroptera is discussed.

BIOLOGICAL INTERACTIONS: IMMUNOCHEMISTRY

Krywienczyk, J.; Takai, S.; Mathieson, B.A. 1979. Cerato-ulmin, a wilting toxin of *Ceratocystis ulmi:* development of antiserum against the toxin. Ann. Phytopathol. Soc. Japan 45(5): 745-757.

Krywienczyk, J.; Dorworth, C.E. 1980. Serological relationships of some fungi of the genus *Pythium*. Can. J. Bot. 58(12): 1412-1417.

Antisera were prepared to nine species of Pythium and serological interrelationships were investigated using the double diffusion technique in agarose and immunoelectrophoresis. Among the nine species the following groups were distinguishable: P. aphanidermatum and P. butleri appear to be identical and different from the other species investigated. Pythium coloratum and P. dissotocum were closely related to each other but very distantly related to the remaining species. Pythium pyrilobum cross-reacted strongly with the homologous antiserum, and only faintly with other antisera. The last group includes very cross-reactive species: P. debaryanum, P. irregular, P. mamillatum, P. sulvaticum and P. ultimum.

Takai, S.; Hiratsuka, Y.; Krywienczyk, J.; Richards, W.C.; Davies, Y. 1980. Evidence of the presence of the toxin cerato-ulmin in the synnema head fluid of *Ceratocystis ulmi*. Can. J. Bot. 58: 669-675.

BIOLOGICAL INTERACTIONS: BIOLOGICAL SYSTEMS ANALYSIS

Haliburton, W. 1978. A comparison of empirical equations used to approximate the drop/stain diameter relationship of volatile oil-based spray fluid on Kromekote paper. Forest Pest Manage. Inst. Inf. Rep. FPM-X-8. 16 pp.

Empirical equations to describe the drop size to stain size relationship of spray drops on Kromekote paper are derived for eight models, linear, exponential and polynomial, using data from calibrations of four similar oil-based forest spray formulations. Their goodness of fit to the data and their upward and downward extrapolations are compared. Three exponential models include an adjusting term to compensate for evaporative shrinkage of the drops. One seems to provide a good estimate of the relationship to be expected in the absence of evaporative shrinkage. Based on this a model is developed to express the relationship obtained for the smaller drops where the diameter shrinkage can be no greater than that permitted by a short term evaporated residual volume fraction limit. The use of polynomial models is questioned. Within limits the simple exponential model is adequate for volume deposit measurement but not for drop size spectrum analysis for this moderately volatile formulation.

PHYSIOLOGICAL & GENETIC MECHANISMS: PHEROMONES

Grant, G.G.; McCarty, L. 1977. Effect of age on calling behaviour and mating success of whitemarked tussock moths. Can. For. Serv. Bi-mon. Research Notes 33(1):2-3.

Grant, G.G. 1977. Interspecific pheromone responses of tussock moths and some isolating mechanisms of eastern species. Env. Entomol. 6(5):739-742.

Laboratory tests with 5 species of Orgyia tussock moths (O. leucostigma [J.E. Smith], O. definita Packard, O. antiqua [L.], O. pseudotsugata [McDunnough], and O. cana [P. vetusta] Edwards) revealed that all species show some degree of pheromone cross stimulation which range from weak (16-41% response) to strong (>60%). O. definita showed the most exclusive sex pheromone system because they were strongly stimulated by fewer species and only homospecific males responded strongly to definita females.

In the laboratory, (Z)-6-heneicosen-11-one, the female sex pheromones of O. pseudotsugata, was sexually stimulating to O. leucostigma and O. antiqua males but not to O. definita males. In electroantennogram tests, O. definita males were 100-fold less sensitive than the other 2 species to this compound. In the field, the chemical attracted O. leucostigma, O. antiqua, and the pine tussock moth, Dasychira plagiata (Walker). Several isolating mechanisms were described which help maintain the species integrity of these sympatric eastern tussock moth species.

Sanders, C.J.; Daterman, G.E.; Ennis, T.J. 1977. Sex pheromone response of *Choristoneura* spp. and their hybrids (Lepidoptera: Tortricidae). Can. Entomol. 109: 1203-1220.

Field studies in Ontario, Oregon, and California on interspecific attraction and inhibition among the coniferophagous species of Choristoneura (the spruce budworm and its allies) confirmed specific pheromoneal differences among the species. Of the three species that are mutually attractive and whose males are attracted by blends of

trans- and cis-11-tetradecenal, C. fumiferana, C. biennis, and C. occidentalis, catches of C. fumiferana males in traps baited with C. fumiferana females were significantly reduced by the presence of females from a second group in which it is believed the females produce trans-11-tetradecenyl acetate. Catches of C. occidentalis males by C. occidentalis females were not affected in this way. F_1 hybrids and backcrosses between an aldehyde-producing species and an acetate-producing species produced females that were attractive to males of one or other of the parent species, although some females were not attractive to either. Individual females never attracted males of both parent species, and of those that were attractive more were attractive to males of the aldehyde species than to males of acetate species. The results suggest sex-controlled inheritance and expression.

Lalanne-Cassou, B.; Percy, J.; Macdonald, J.A. 1977. Ultrastructure of sex pheromone gland cells in *Lobesia botrana* Den & Schiff. (Lepidoptera: Olethreutidae). Can. J. Zool. 55: 672-680.

In newly emerged and 48-h-old female adults of Lobesia botrana the sex pheromone gland cells are columnar. Organelles characteristic of lipid-producing cells are very prominent. Smooth tubular endoplasmic reticulum is extensively developed but few lipid droplets are observed. Numerous microbodies are present and are located, along with the Golgi complexes, primarily in the vicinity of the nucleus. The apical plasma membrane is folded. The cuticle overlying the gland cells differs from unmodified cuticle in the number and location of epicuticular filaments. They originate near the bases of the furrows between the apical folds.

Weatherston, J.; Percy, J. 1977. Sex Pheromones of moths. Endeavour, New Series 1: 83-87.

An invited review article concerning the production, chemical identification and practical use of sex pheromones of moths by drawing examples from the work of both authors.

Grant, G.G. 1978. Field trial on disruption of pheromone communication of tussock moths. J. Econ. Entomol. 71: 453-457.

Pheromone disruption experiments were carried out by releasing and recapturing laboratory-reared, whitemarked tussock moth (WMT), Orgyia leucostigma (J.E. Smith), males in small plots (324 m^2). One plot was treated with (Z)-6-heneicosen-11-one, the Douglas-fir tussock moth pheromone, released from planchet evaporators at an estimated rate of 4.4 mg/plot/day (= ca. 140 mg/ha/day). In 14 replicates, 50% of the 864 released males in the untreated plot were recaptured but only 1.2% of 869 released males in the treated plot were recaptured. The average disruption was 97.6%.

The same chemical was effective in disrupting pheromone communication of feral populations of WMT and pine tussock moth (PTM). Dasychira plagiata (Walker), in similar

small plot tests. Planchet evaporators, releasing the chemical at ca. 4.4 mg/plot/day, caused 92-100% disruption of PTM and 96-100% disruption of WMT. Commercially prepared hollow fiber dispensers, releasing pheromone at rates of 0.7, 1.2 and 1.6 mg/plot/day (= ca. 20, 40 and 50 mg/ha/day, respectively), caused 65-96% disruption of PTM and 76-92% disruption of WMT. (Z)-6-heneicosen-11-one offers promise for pheromone communication disruption of several tussock moth species.

Grant, G.G. 1978. Morphology of the presumed male pheromone glands on the forewings of *Tortricid* and *Phycitid* moths. Ann. Entomol. Soc. Am. 71(3):423-431.

The morphology and histology of the male scent glands of tortricid and phycitid moths, consisting of a costal fold on the forewing, are described and compared. The tortricid species studied were Archips argyrospilus (Walker), A. mortuanus Kearfoot, A. rosanus (L.), A. cerasivoranus (Fitch), and Choristoneura rosaceana (Harris). The phycitids were Plodia interpunctella (Hubner), Vitula edmandsae (Packard), and Cadra cautella (Walker). Although the tortricid glands fold dorsally and phycitid glands ventrally, their morphology and histology are quite similar. The folds contain 1 or 2 hairpencil tufts (scent brushes) which, in the closed fold, are in intimate contact with a modified glandular scale tract. The glandular cells into which the latter scales insert are generally large with a prominent nucleus, an apical cytoplasmic reservoir with indications of a microvillous border, and sometimes a cuticular extension of the scale base into the reservoir. The cells at the base of the hairpencils are atrophied except in V. edmandsae where they appear glandular and, thus, may be secretory.

The folds of V. edmandsae and P. interpunctella also have a patch of bristle-like scales and associated glandular cells. These bristles are not found in any of the other species and their function is unknown. The fold of C. cautella lacks glandular tissue and that of C. rosaceana is rudimentary lacking hairpencils and glandular cells. These folds are probably nonfunctional in terms of releasing a male scent.

The distribution of scent scales in the Tortricidae is discussed.

Percy, J. 1978. Haemocytes associated with basement membrane of sex pheromone gland of *Trichoplusia ni* (Lepidoptera:Noctuidae). Ultrastructural observations. Can. J. Zool. 56:238-245.

In female Trichoplusia ni, granular haemocytes are observed near the basement membrane of developing sex pheromone gland cells while plasmatocytes are observed near the basement membrane of unmodified epidermal cells. The basement membrane underlying gland cells is clearly different from that of other epidermal cells. There is a thin amorphous layer (layer 1) which is also present beneath unmodified cells, and a second layer (layer 2) apposing the haemocytes. Layer 2 is distinctly banded which results from tubules similar in dimensions and structural appearance to those observed within granules of the granular haemocytes. The observations indicate that the granules participate in the formation of layer 2 by emptying their contents into the haemocoel next to layer 1.

Weatherston, J.; Grant, G.G.; MacDonald, L.M.; Frech, D.; Werner, R.A.; Leznoff, C.C.; Fyles, T.M. 1978. Attraction of various tortricine moths to blends containing cis-11-tetradecanal. J. Chem. Ecol. 4(5):543-549.

Blends containing cis-11-tetradecenal with the trans isomer or cis-11-tetradecen-1-ol were field tested against the tortricine species Choristoneura conflictana and Croesia semipurpurana. The results indicate that cis-11-tetradecenal alone is a very potent attractant for male C. conflictana whereas male Croesia semipurpurana were strongly attracted to blends of trans/cis-11-tetradecenal in the range 80:20-90:10. Cenopis acerivorana and Choristoneura fumiferana were also caught with mixtures of 11-tetradecenal isomers while Choristoneura fractivittana was very strongly attracted to the mixture of cis-11-tetradecen-1-ol/cis-11-tetradecenal in the ratio 95/5.

Percy, J.E. 1979. Development and ultrastructure of sex-pheromone gland cells in females of the cabbage looper moth, Trichoplusia ni (Hubner) (Lepidoptera: Noctuidae). Can. J. Zool. 57(1): 220-236.

The sex-pheromone-producing gland in female Trichoplusia ni (Hubner) is a modified intersegmental membrane and the gland cells are ductless. Lipid spheres are located throughout gland cells and vary both in number and size relative to the age of the female. Most of the lipid is surrounded by oval to elongate distensions of smooth tubular endoplasmic reticulum which contain the enzyme catalase and are thus micro-peroxisomes. Lipid spheres evert the apical plasma membrane between microvilli, move away from the gland cells, and are stored in the cuticle as discrete lipid deposits. These deposits, in turn, move to the surface of the gland by tubular structures that differ from epicuticular filaments.

Percy, J.; George, J.A. 1979. Abdominal musculature in relation to sex pheromone gland eversion in females of three species of Lepidoptera. Can. Entomol. 111:817-825.

The posterior apophyses in terminal abdominal segments of female moths form part of the sex pheromone gland in each of three species examined [Choristoneura fumiferana (Clem.) (Tortricidae), Trichoplusia ni (Hubner) (Noctuidae), Orgyia leucostigma (J.E. Smith) (Lymantriidae)]. Four groups of paired dorsolateral muscles are attached to the anterior or posterior apophysis and the integument. An additional group is attached to the anterior and posterior aphophyses. The probable relationship of these muscles to the eversion, or protusion, and inversion of sex pheromone glands is discussed.

Grant, G.G.; Frech, D. 1980. Disruption of pheromone communication of the rusty tussock moth, Orgyia antiqua (Lepidoptera: Lymantriidae), with (Z)-6-heneicosen-11-one. Can. Entomol. 112(2): 221-222.

Chisholm, M.D.; Underhill, E.W.; Stack, W.; Slessor, K.M.; Grant, G.G. 1980. (Z)-5, (E)-dodecadienal and (Z)-5, (E)-7-dodecadieniol, sex pheromone components of the forest tent caterpillar, *Malacosoma disstria*. Environ. Entomol. 9: 278-282.

By capillary gas chromatography, mass spectrometry, electoantennogram measurements, and male behavioral response tests, (Z)-5, (E)-7-dodecadienal was identified as the principal component of the sex pheromone of the forest tent caterpillar, Malacosoma disstria (Hubner). (Z)-5, (E)-7-Dodecadien-1-ol was indicated as a secondary component. In field trapping males were attracted to lures containing each component separately but best trapping occurred with aldehyde alcohol ratios between 1:10 and 1:3 n-Dodecanal was also found in female tip extracts.

Sanders, C.J.; Weatherston, J.; Grant, G.G. 1980. Effects of (E)-9-Dodecen-1-YL formate on the sex pheromone response of male spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 112:99-102.

Formates analogous to the aldehyde sex pheromones of several species of Lepidoptera have been shown to have biological activity. (E)-9-Dodecen-1-yl formate was therefore tested against male spruce budworm (C. fumiferana) by EAGs and by field trapping experiments designed to test for attraction, inhibition, and disruption. No biological activity was detected.

Grant, G.G. 1981. Mating behaviour of the whitemarked tussock moth and role of female scales in releasing male copulatory attempts. Ann. Entomol. Soc. Am., 100-105.

The short-range precopulatory behavior of the whitemarked tussock moth, Orgyia leucostigma (J.E. Smith), was observed in the laboratory. Male copulatory behavior is released by tarsal contact with the female's body scales. In the absence of female scales, the male's behavior is significantly altered and he has difficulty orienting properly to the female. As a result the male takes twice as long to initiate a copulatory attempt and takes twice as long to achieve copulation. In addition, the percentage of encounters that lead to at least one copulatory attempt is significantly reduced.

Plasticene® models coated with female tussock moth scales elicited normal courtship and copulatory behavior as did freeze-dried tussock moth females with scales intact. Plasticene models without scales or coated with scales from the spruce budworm, Choristoneura fumiferana (Clemens), elicited abnormal mating behavior and significantly reduced copulatory responses. It is not clear whether chemical or mechanical characteristics of the female scales release male copulatory behavior.

Grant, G.G.; Frech, D.; MacDonald, L.; Doyle, B. 1981. Effect of additional components on a sex attractant for the oak leaf shredder, *Croesia semipurpurana* (Lepidoptera: Tortricidae). Can. Entomol. 113: 449-451.

Meighen, E.A.; Slessor, K.N.; Grant, G.G. 1981. A bioluminescence assay for aldehyde sex pheromones of insects. Experientia 37: 555-556.

Meighen, E.A., Slessor, K.N.; Grant, G.G. 1981. Bacterial bioluminescence: applications to entomology. *In* M.A. Deluca and W.D. McElroy, eds. Bioluminescence & Chemiluminescence, Proceedings Second International Congress Academic Press, New York.

Grant, G.G. 1983. Sex pheromones of the maple leaf roller *Cenopis acerivorana* (Lepidoptera: Tortricidae). Can. Entomol. 115: 189-194.

Pheromone gland rinses of female maple leaf roller moths were analyzed by capillary gas chromatography and found to contain (Z)-11-tetradecenal, (E)-11-tetradecenal, tetradecanal, (Z)-11-tetradecenyl acetate, (E)-11-tetradecenyl acetate, and tetradecyl acetate in the average ratio of 33:20:8:21:17:2 for single female analysis and 3[illegible]:16:6:16:27:3 for a pooled extract of 55 females. Identity of the tetradecenals, the tetradecenyl and tetradecyl acetates was confirmed by gas chromatography - mass spectrometry. Electroantennogram analysis indicated that (Z)-11-tetradecenal were the most stimulating compounds tested. In field tests, only three components (Z)-11-tetradecenal, (E)-11-tetradecenal and (Z)-11-tetradecenyl acetate, in the microgram ratio of 65:35:10, were necessary for optimum attraction. Another tortricid moth, Archips griseus, was attracted to some of the aldehyde mixtures.

PHYSIOLOGICAL & GENETIC MECHANISMS: GROWTH REGULATORS

Retnakaran, A. 1978. Conditioned feeding preference in the forest tent caterpillar. Can. For. Serv. Bi-mon. Res. Notes 34:32.

Retnakaran, A. 1978. Insect Growth Regulators as control agents for the eastern spruce budworm. Proceedings of Insect Growth Regulator Workshop. Maine Life Sci. Misc. Rep. 198: 9-30.

Retnakaran, A.; Jobin, L.; Granett, J.; Ennis, T.J. 1978. Scanning electron microscopic study of wax formation in the balsam woolly aphid, *Adelges picea* (Homoptera: Adelgidae). Can. Entomol. 111:67-72.

Scanning electron micrographs of balsam woolly aphid, Adelges piceae Ratz., show ribbon-like wax secretion in the dorso-median, marginal and inter-tergal regions. Longitudinal grooves in the ribbons indicate that secretions from a row of cells fuse together to form bands of wax. Most of the ribbons appear as extensions of the tergal sclerites. Post-notal plates are conspicuous in the dormant first instar, and in the adults characteristic wax plates with crater-like pits are evident.

The chemistry of wax in related species and a rationale for control using juvenile hormone analogs are discussed.

Retnakaran, A.; Kaupp, W.J.; Howse, G.M. 1978. Experimental aerial application of insect growth regulators against the spruce budworm, *Choristoneura fumiferana* (Clemens) in Thessalon (1976) and Hearst (1977). Forest Pest Manage. Inst. Inf. Rep. FPM-X-19, 29 pp.

Experimental aerial application of several Insect Growth Regulators against the spruce budworm at Thessalon (1976) and Hearst (1977) showed that: 1) Dimilin at 140 g/ha is ineffective with or without a sticker; 2) Dimilin when applied twice with an interval of 1 week between sprays at 140 and 70 g/ha (2 and 1 oz./acre) caused 78.1% reduction in spruce budworm population and provides good foliage protection on white spruce. However, it is less effective on balsam fir; 3) RO-103108, like other juvenile hormone analogs has marginal effects and does not merit further testing; 4) PH 60-41, which is not a moult inhibitor even though it is an analog of Dimilin at 140 g/ha caused around 70.1% population reduction on both balsam fir and white spruce and warrants further study; and, 5) EL-494 which is a moult inhibitor, at 140 g/ha caused 60.1% reduction on both tree species and requires further testing.

Retnakaran, A.; Smith, L.; Tomkins, W. 1978. Absence from maple sap of Dimilin applied as a soil drench. Can. For. Serv. Bi-mon. Res. Notes 35:16-17.

Ennis, T.J. 1979. Teratogenicity, mutagenicity and oncogenicity testing of Dimilin. Maine Life Sci. & Agr. Exp. Stn. Misc. Rept. 219: 26-35.

Retnakaran, A. 1979. Effect of a new moult inhibitor (EL-494) on the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 111: 847-850.

In laboratory tests on the spruce budworm, Choristoneura fumiferana (Clemens), EL-494 , a new moult-inhibiting insect growth regulator, was found to be more active than Dimilin. The EC_{50} determined by diet tests was 0.250 ppm for the 3rd, 0.249 for the 4th, 0.287 for the 5th, and 0.486 for the 6th instars. Stadial sensitivity was not detected.

In the greenhouse tests this compound was found to be resistant to leaching and UV-degradation; the compound remained active on spruce foliage for at least 15 days. In preliminary field tests EL-494 showed good potential as a control agent.

Retnakaran, A. 1979. The potential of Insect Growth Regulators as ecologically acceptable agents for controlling forest insect pests. Pages 151-158 *In* W.E. Waters, ed. Current topics in Forest Entomology: Selected papers from the XVth International Congress of Entomology U.S. Gov't. Print. Off., Washington, D.C.

Retnakaran, A. 1979. Recent developments in the use of Insect Growth Regulators in spruce budworm control. (CANUSA-IGR Workshop). Maine Life Sci. Misc. Rep. 219: 11-17.

Retnakaran, A.; Smith, L.; Tomkins, B.; Granett, J. 1979. Control of forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae), with Dimilin®. Can. Entomol. 111: 841-846.

Dimilin (25% wettable powder) was mixed in water and sprayed from a Grumman Agcat aircraft equipped with four micronair units at the rate of 70 g (active ingredient)/ 4.67 L/ha on two stands of trembling aspen, Populus tremuloides Michx., heavily infested with forest tent caterpillar, Malacosoma disstria Hubner. The material was applied when the insects were in the first- and second-instars and the trees were starting to flush. Spray deposit analysis using a dye, Rhodamine-B, in the spray mix and spray plates in the plots indicated that conditions for spraying in the morning were better than those in the evening as expected. Total control of the forest tent caterpillar with very little defoliation of the trees was achieved.

Granett, J.; Robertson, J.; Retnakaran, A. 1980. Metabolic basis of differential susceptibility of two forest Lepidopterans to Diflubenzuron. Ent. Exp. & Appl. 28: 295-300.

Sixth instar Choristoneura occidentalis Freeman and 5th instar Orgyia pseudotsugata (McDunnough) were fed ring-labelled ^{14}C-diflubenzuron coated on Douglas-fir needles. After ingestion the gut was purged of radioactive needle residues with artificial diet. Radioactivity in body and frass extracts and residues were measured. Diflubenzuron in extracts was separated from metabolites by thin layer chromatography.

Ninety percent and 86% of the ingested diflubenzuron passed through the body without being absorbed in C. occidentalis and O. pseudotsugata, respectively. Bodies of C. occidentalis retained 0.3% of ingested diflubenzuron, while O. pseudotsugata retained 5.3%. This difference in % of diflubenzuron retention in the body was negatively correlated with % relative metabolism in the two species. Relative toxicities of diflubenzuron to the two species may be related to % retained diflubenzuron which may be due to a significant difference in relative metabolism.

Retnakaran, A. 1980. Effect of 3 new moult inhibiting insect growth regulators on the spruce budworm. J. Econ. Entomol. 73: 520-524.

Three new moult-inhibiting insect growth regultors, BAY SIR 8514 (N-[[[4-(trifluoromethoxy)phenyl] amino] carbonyl]-2-chlorobenzamide), LY-127603 (N-[[[50(4-bromophenyl)-6-methylpyrazinyl] amino] carbonyl]-2-chlorbenzamide), and LY-131215(2,6-dimethyoxy-N-[5-[4(pentafluorethoxy) phenyl]-1,3,4-thiadiazol-2-yl] benzamide) were tested in the laboratory and in the greenhouse against Choristoneura fumiferana (Clemens). In addition, BAY SIR 8514 was tested in the field. The EC_{50} ranged from 0.05 to 0.14 ppm in diet tests and the compounds were stable to autoclaving and UV-

exposure from a sun lamp. Greenhouse tests indicated that the equivalent of 35 g in 4.7 liters/ha gave 95% control for BAY SIR 8514, 98% for 127063 and 83% for 131215. Experimental aerial application of BAY SIR 8514 showed that at 210 g/ha or more, the level of control achieved was similar to that of the carbamate pesticide, aminocarb at 70 or 70 + 70 g/ha.

Retnakaran, A.; Granett, J.; Robertson, J. 1980. Possible physiological mechanisms for the differential susceptibility of two forest lepidoptera to Diflubenzuron. J. Insect Pathol. 26: 385-390.

In an attempt to explain the physiological mechanisms for the differential susceptibility of insects to the chitin synthesis inhibitor, diflubenzuron, chitin content, chitin synthesis, and retention of ingested ^{14}C-diflubenzuron in two forest Lepidoptera were investigated. The spruce budworm, Choristoneura fumiferana a refractory species, had less chitin and retained less of the ingested material than the forest tent caterpillar, Malacosoma disstria, a species highly sensitive to diflubenzuron. No difference in the chitin synthesis pattern during the 6th stadium was observed in the two species. It is concluded that the primary reasons for the increased susceptibility of the forest tent caterpillar to this compound was the increased retention of ingested diflubenzuron and, to a lesser extent, the increased retention of ingested diflubenzuron and, to a lesser extent, the increased chitin content.

Retnakaran, A.; Smith, L. 1980. Web-spinning in spiders is unaffected by moult-inhibiting Insect Growth Regultor BAY SIR-8514. Can. For. Serv. Bi-mon. Res. Notes 36:19-20.

Retnakaran, A. 1981. Toxicology and efficacy of insect growth regulators aerially applied against the spruce budworm at Hearst (1978), Wawa (1979) and the French River area (1980). Forest Pest Manage. Inst. Inf. Rep. FPM-X-45, 63 pp.

During 1978 to 1980, 5 different experimental moult-inhibiting Insect Growth Regulators (EL-494, L-1215, L-7063, BAY SIR-8514, and UC-62644) were studied in the laboratory and in the greenhouse. The most active material was UC-62644 followed by BAY SIR-8514. The other 3 compounds were not very effective. UC-62644 manifested its effects within 48 h whereas the others took more than 1 week. Greenhouse trials showed similar patterns of activity.

Retnakaran, A. 1982. Laboratory and field evaluation of a fast-acting insect growth regulator against the spruce budworm, Choristoneura fumiferana (Lepidoptera: Tortricidae). Can. Entomol. 114:523-530.

UC-62644, a moult-inhibiting insect growth regulator (IGR) belonging to the benzoylphenylureas, had an EC_{50} of 0.1 to 0.2 ppm in a meridic diet for the 3rd to 6th larval instars of the spruce budworm, Choristoneura fumiferana Clemens. The effects of the IGR were apparent less than 48 h after ingestion and there was evidence for

some contact toxicity. The larvae were unable to discriminate between IGR-treated and untreated diet. Experimental aerial application of the IGR revealed that at 70 g in 4.7 L/ha it effectively controlled spruce budworm populations and afforded foliage protection. These results were comparable with those obtained with Matacil applied at the recommended rate.

Retnakaran, A. 1982. Noninvolvement of mixed function oxidases in Dimilin metabolism. Can. For. Serv. Res. Notes 2(1): 1.

Retnakaran, A.; Smith, L. 1982. Reproductive effects of insect growth regulators on the white pine weevil, *Pissodes strobi* (Coleoptera: Curculionidae). Can. Entomol. 114: 381-383.

Retnakaran, A.; Tomkins, W. 1982. Effectiveness of moult-inhibiting insect growth regulators in controlling the oak leaf shredder. Can. For. Serv. Res. Notes 2(1):5-6.

PHYSIOLOGICAL & GENETIC MECHANISMS: GENETIC MECHANISMS

Ennis, T.J. 1978. An orange-eye mutant of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. J. Genet. Cytol. 20: 427-429.

A mutant adult phenotype of the spruce budworm, Choristoneura fumiferana (Clemens), possesses orange eyes in place of the normal dark purple wild type. Larvae are paler than wild type, and testis pigment is orange instead of purple. The mutant phenotype is due to the expression of a recessive autosomal gene, designated or.

Ennis, T.J.; Charlebois, N. 1978. Fractionation of spruce budworm testis cells by velocity sedimentation. Can. For. Serv. Bi-Monthly Res. Notes 34: 30.

Ennis, T.J. 1979. Detection and isolation of induced chromosome aberrations in Lepidoptera. Experientia 35: 1153-1154.

An embryo chromosome technique combined with larval testes sampling permits isolation within 1 generation of lepidopteran strains carrying chromosome aberrations.

Ennis, T.J. 1981. The sterile male approach to the control of the spruce budworm. *Choristoneura fumiferana*. Reprint from Sterile Insect Technique and Radiation in Insect Control, pp 389-393.

PESTICIDE TOXICOLOGY & EFFICACY: INSECTICIDE TOXICOLOGY

Carrow, J.R.; Puritch, G.S.; Nigam, P.C. 1977. Field test of Furadan and Baygon against balsam woolly aphid in British Columbia. Can. For. Serv., Bi-Mon. Res. Notes 33(3): 10.

Nigam, P.C.; Buckner, C.H. 1978. Evaluation of pesticides for control of forest pests in Canada and their impact on environment. Proc. 8th World Forestry Congress, Jakarta, Indonesia, 16-28 October, 1978. 8 pp.

Aerial application of chemical pesticides is carried out on millions of hectares annually for protection of foliage from ravages of insect pests. Research on biological pesticides is underway in order to replace chemicals. An intensive research program on short and long term impact of the pesticides on forest ecosystems especially on non-target fauna is carried out. No apparent long term adverse effects of the operational control strategies, practiced at the moment, have been found on the various components of the forest ecosystem.

DeBoo, R.F. 1980. Experimental applications of permethrin by mistblower for control of spruce budworm in Québec, 1975-1978. Can. For. Serv. Bi-Mon. Res. Notes 36(5): 23-24.

DeBoo, R.F.; Blais, J.R. 1980. Relative toxicity of aminocarb to wandering and mining second-instar larvae of the spruce budworm. Can. For. Serv. Bi-Mon. Res. Notes 36(4): 9-10.

DeBoo, R.F. 1981. Experimental aerial applications of permethrin for control of *Choristoneura fumiferana* in Québec, 1976-1977. Forest Pest Manage. Inst. Inf. Rept. FPM-X-41, 24 pp.

This report summarizes the results of two years work using permethrin for the control of the eastern spruce budworm. The tests, with permethrin applied aerially at dosages ranging from a single treatment at 18 g AI/ha through a series of double and triple applications and single applications at 35 and 70 g AI/ha showed that excellent protection of the foliage was achieved using either a double application at 18 g AI/ha or a single application at 70 g AI/ha. Details of oil or water emulsion sprays and an assessment of the spray deposit are included in this report.

Hopewell, W.W. 1977. Field evaluation of eight insecticides for control of *Neodiprion lecontei* on red pine, *Pinus resinosa*, by simulated aerial spray. Forest Pest Manage. Inst. Inf. Rep. FPM-X-7, 20 pp.

Eight insecticides, including a moult inhibitor and a nuclear polyhedrosis virus preparation, were tested for control of the redheaded pine sawfly, Neodiprion lecontei. The formulations were applied as simulated aerial spray deposits to single red pine trees, Pinus resinosa, ca 2.4 metres in height. Phosphamidon and permethrin

were the most active, the minimum effective deposits for both being 35 g AI/3 L/ha for excellent foliage protection; aminocarb at 100 g AI/3.5 L/ha and propoxur and fenitrothion at approximately 150 g AI/3 L/ha were ineffective. The moult inhibitor EL-494, at 160 g AI/3 L/ha also gave good foliage protection. Four formulations of a nuclear polyhedrosis virus, applied at nominal rates of 5.8 x 10^9 polynuclear inclusion bodies per hectare in 8.8 litres when larvae were in 3rd and 4th instar, gave some foliage protection. The virus formulated from a crude preparation was more effective than that from a purified form of the virus.

Randall, A.P.; Zylstra, B.F.; McFarlane, J.W. 1977. The effect of fenitrothion and aminocarb on second instar spruce budworm (*Choristoneura fumiferana* Clem.) in Quebec in 1977. Forest Pest Manage. Inst. Inf. Rept. FPM-X-5, 24 pp.

Two treatments of fenitrothion at 0.28 A.I. Kg/ha were applied to an extremely high population of spruce budworm, Choristoneura fumiferana (Clem.), to control 2nd-instar larvae (L_2) and prevent severe defoliation of balsam fir (Abies balsamea) and spruce (Picea spp.) in the Gaspe region of Quebec. This was followed by a third application of 0.07 kg A.I./hectare of aminocarb when larval development had reached 25% 4th-instar (L_4). Results of the treatments indicated good control of L_2 larvae with populations being reduced an average of 70% by the first two applications. The final application of aminocarb showed no subsequent reduction in the remaining larval population. This can be attributed to poor droplet coverage and the fact that the insecticide was applied before the shoots were fully flared. Foliage protection within the treated area was very good compared to the untreated area. Only 46% defoliation on fir and 40% on spruce ocurred in the treated area compared to 99% on fir and 82% on spruce in the untreated check block.

Puritch, G.S.; Nigam, P.C.; Carrow, J.R. 1980. Chemical control of balsam woolly aphid (Homoptera: Adelgidae) on seedlings of *Abies amabilis*. J. Entomol. Soc. B.C. 77:15.

Assessment was made of the effectiveness of four insecticides for eradicating Adelges piceae (Ratz.) from Abies seedlings. Seedlings with overwintering immature aphids were top-dipped in the insecticides in fall or spring (before or after cold storage), while those with mature, egg laying aphids were treated in spring. The overwintering immature aphids were completely killed by all of the insecticides and it was recommended that any one of the following treatments would provide sanitation of Abies from aphids during this stage. One percent propoxur suspension; 2.0% carbaryl suspension; 2.0% Insecticidal Soap solution; 0.5% permethrin emulsion. Treatment of mature aphids was less effective due to relative tolerance of bwa eggs and it was recommended that treatment during this stage of the aphid be avoided.

Zylstra, B.F.; Obarymskyj, A. 1981. Experimental aerial applications of permethrin, carbaryl and chlorpyrifos-methyl for control of eastern spruce budworm, *Choristoneura fumiferana* (Clem.) in New Brunswick in 1980. Forest Pest Manage. Inst. Inf. Rept. FPM-X-56. 14 pp.

Three insecticides, permethrin [3-phenoxybenzyl (+) trans-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclorpropanecarboxylate], carbaryl (1-naphthyl methylcarbamate) and chlorpyrifos-methyl [0,0-dimethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate] were field tested for control of the spruce budworm, Choristoneura fumiferana (Clem.) in New Brunswick in 1980. All formulations were applied by a Cessna Agtruck equipped with AU 3000 Micronair rotary atomizers, flying at 160 km/h. Swath interval was 60 metres; height above the forest canopy was 10-20 m. A double application of permethrin at 17 g (A.I.) in 1.46 L of Shell ID 585/ha resulted in 79% corrected mortality against 3rd and 4th instar spruce budworm larvae on balsam fir and 63% on red-black hybrid spruce sample trees. A single application of permethrin at the same dosage rate resulted in only 45.8% and 59.6% corrected mortalities on balsam fir and hybrid spruce, respectively. A double application of carbaryl applied at 280 g (A.I.)/ha in a total volume of 1.46 L/ha resulted in average, corrected, budworm mortality of 54.7% on balsam fir and 62.4% on red-black hybridized spruce. Chlorpyrifos-methyl, when applied as two applications of 70 g (A.I.)/ha each, resulted in corrected mortalities of 61.0% on balsam fir and 27.7% on hybrid spruce. Defoliation after each treatment was less than 10%, while untreated areas experienced 52-57% defoliation on balsam fir samples and 14-17% on the hybrid spruce.

Nigam, P.C.; Simmons, G.A. 1982. Field evaluation of an ovicide (Dormant oil) for the management of oak leaf roller *(Archips semiferanus* [Walker]. Gt. Lakes Entomol. (in press).

PESTICIDE TOXICOLOGY & EFFICACY: INSECTICIDE FIELD EFFICACY

Morris, O.N. 1977. Relationship between microbial numbers and droplet size in aerial spray applications. Can. Entomol. 109: 1319-1323.

Experiments were designed to determine the actual number of spores and crystals of Bacillus thuringiensis (B.t.) and of nuclear polyhedral virus and entomopoxvirus deposited at ground level per unit area and to determine any change in spore crystal ratio following aerial application in forested plots.

The results indicate that: (1) The estimation of B.t. aerial spray deposits by the commonly used agar plan method grossly underestimates the deposit rates of active ingredient. The tracer dye method more accurately estimates deposit rates for both B.t. and entomopathogenic viruses. As a dye 0.1% Erio Acid Red XB is recommended. (2) The relationship between droplet size and the number of spores and crystals or virus inclusion bodies/droplet is curvilinear. This relationship probably holds true regardless of spray volume rate. All visible spray deposits at ground level contained some active ingredient. (3) With B.t. sprays the spore crystal ratio emitted from the aircraft is not changed upon target impact.

Armstrong, J.A.; Yule, W.N. 1978. The distribution of aerially applied spray deposits in spruce trees. Can. Entomol. 110:1259-1267.

This study demonstrates that a finely atomized spray applied to a white spruce forest under suitable weather conditions will give a deposit on the outer portions of the tree with a variation of only about 50% in spray deposit but with significantly less deposit on the inner, lower portions of the tree.

Randall, A.P. 1980. A simple device for collecting aerial-spray deposits from calibration trials and spray operations. Can. For. Serv. Bi-Mon. Res. Notes 36:5.

Randall, A.P.; McFarlane, J.; Zylstra, B.F.; Desaulnier, R. 1981. Multiple applications of pesticides on high populations of early instar spruce budworm larvae (Québec, 1977). Forest Pest Manage. Inst. Inf. Rep. FPM-X-42, 78 pp.

A 120,960 hectare area of severely budworm-infested forest in the Gaspe region of Quebec was sprayed in 1977 with two early applications of fenitrothion and a single late application of aminocarb to control the second, early third and early fourth instars of Choristoneura fumiferana (Clem.) using Douglas DC-6B spray aircraft. The data and results were assessed from both an operational and experimental point of view to ascertain and quantify dosage - mortality effects of the sprays and resultant foliage protection. Analysis of the data indicated that maximum cost - benefit was obtained from the early spray strategies in terms of larval reduction and foliage protection.

Randall, A.P. 1982. Equipment and technique for rapid determination of second-instar larval counts from branch samples. Can. For. Serv. Res. Notes 2(2): 9-12.

APPLICATION TECHNOLOGY: DISPERSAL SYSTEMS

Armstrong, J.A. 1978. A trailer-mounted insecticide mixing-loading unit. Mosq. News 38(1):19-24.

Research and small operational applications to study efficacy of pesticides applied by air or ground application equipment are frequently jeopardized by the use of poorly designed, ineffective mixing equipment. The result is the application of a badly mixed and frequently contaminated formulation. A trailer-mounted mixing-loading unit capable of handling suspensions, emulsions and solutions is described. The mixing tank is fitted with a paddle system, can be readily cleaned, and has accurate metering of formulation. It has a self-contained system for power supply. An extra tank to hold clean solvent permits quick cleaning of the plumbing to prevent cross-contamination of the test batches of material.

Johnson, W.T.; Cunningham, J.C.; Kaupp, W.J.; Edwards, J.C. 1978. Insect virus application with a cold fog generator. Can. For. Serv. Bi-Mon. Res. Notes 34(4): 25-26.

Edwards, J.C. 1979. The use and potential of helicopters in forest pest management. Forest Pest Manage. Inst. Inf. Rept. FPM-X-16, 212 pp.

The purpose of this study was to explain the contemporary state of the art in Canada of forest spraying by helicopter, and to evaluate the feasibility of a proposed research program to optimize treatment results through the development of specialized helicopter spraying equipment, techniques and operational guidelines.

Randall, A.P.; Moore, A.; Carter, N. 1980. Cessna Ag-truck calibration trials for the dispersal of aqueous formulations of *Bacillus thuringiensis kurstaki* in Newfoundland, 1979. Forest Pest Manage. Inst. Inf. Rept. FPM-X-38, 33 pp.

3 different water formulations of Bacillus thuringiensis (Thuricide 16B, Thuricide 24B, and Novabac N45B), to be sprayed at the rate of 20 BIU/5.85 L/ha, were tested for rate of flow and droplet spectrum characteristics using a Cessna Ag-truck fitted with twenty No. 8004 and twenty No. 8006 Spraying Systems nozzles. Results of four calibration tests indicated that all formulations flowed through the system, but produced larger spray droplets than the recommended mass median diameter of 90 µm. Problem areas in formulations, assessment of spray deposits, and equipment calibration are discussed.

Johnson, W.T.; Morris, O.N. 1981. Cold fog applications of pesticides for control of *Malacosoma disstria*. J. Arboriculture 7:246-251.

Tests were conducted to determine the effectiveness of a ULV fog generator in dispersing Bacillus thuringiensis and B.t. combinations of synthetic organic insecticides in liquid formulations against the forest tent caterpillar, Malacosoma disstria. Those formulations containing superior horticultural oil as the carrier gave better control over those in which water was the sole carrier. The water portion of the mist particle was subject to rapid evaporation and appeared to be a major cause for poor control in the system described. The ULV fogger with some mechanical modifications, can be used effectively for application of microbial insecticides to trees. Thuricide 16B combined with acephate in an oil emulsion carrier was highly effective in reducing tent caterpillar populations.

Moore, A.; Morris, O.N. 1982. An improved technique for dosing larvae of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) with measured quantities of *Bacillus thuringiensis* Can. Entomol. 114: 89-91.

APPLICATION TECHNOLOGY: SPRAY CLOUD BEHAVIOUR

Armstrong, J.A. 1979. Effect of meteorological conditions on the deposit pattern of insecticides. Mosq. News 39(1):10-13.

The deposit pattern of a spray cloud is affected by micrometeorological conditions at the time of application. Basic equipment requirements for determining suitability of weather conditions for spraying are described.

APPLICATION TECHNOLOGY: PESTICIDE FORMULATIONS

Sundaram, K.M.S.; Sundaram, A. 1981. Effect of additives on the persistence of aminocarb in conifer foliage. Can. For. Serv. Res. Notes 1(3): 18-21.

Sundaram, K.M.S.; Sundaram, A. 1982. Influence of formulation on droplet size, deposit concentration, and persistence of fenitrothion in conifers following a simulated aerial application. Can. For. Serv. Res. Notes 2(1): 2-5.

ENVIRONMENTAL CONCERNS: ENVIRONMENTAL IMPACT

Kingsbury, P.D.; Beveridge, W.J.G. 1977. A simple bubbler for sorting bottom fauna samples by elutriation. Can. Entomol. 109: 1265-1268.

A simple bubbler for separating insects and other macroinvertebrates from aquatic bottom samples by elutriation is described. The apparatus is simple in construction and use and separated all groups of aquatic organisms from stream bottom samples with about 99% overall efficiency.

Buckner, C.H.; McLeod, B.B. 1977. Impact of experimental spruce budworm (*C. fumiferana* Clemens) suppression trials upon forest dwelling birds in Newfoundland in 1977. Forest Pest Manage. Inst. Inf. Rep. FPM-X-9, 80 pp.

Immediate and short-term consequences of experimental spruce budworm (Choristoneura fumiferana Clemens) suppression trials upon the forest dwelling bird complex were studied. A series of trials employing aminocarb at the emitted dosage rates of 0.070 kg AI/ha x 3 and 0.087 kg AI/ha x 2 did not damage bird populations or interrupt breeding activity. Trials involving two applications of fenitrothion (0.210 kg AI/ha) followed by aminocarb (0.070 kg AI/ha) caused a short-term decline in the activ-

ity of warblers (family Parulidae). Acephate (0.056 kg AI/ha) combined with Bacillus thuringiensis Berliner (19.8 BIU/ha) and applied twice caused a reduction of warbler activity.

Plot searches after each trial failed to recover any dead birds; no sick or stressed birds were observed.

Kingsbury, P.D. 1978. Aquatic impact studies by FPMI in Quebec Spruce Budworm Spray Block 205, 1977. Forest Pest. Manage. Inst. Inf. Rep. FPM-X-12, 85 pp.

Extensive studies were carried out in a lake and a number of streams treated with two 0.280 kg/ha applications of fenitrothion followed by a 0.070 kg/ha aminocarb treatment applied for spruce budworm, Choristoneura fumiferana, Clemens, control. No dramatic adverse effects on lake zooplankton, benthos or fish populations occurred, but a significant effect on shallow dwelling baetid mayfly nymphs was indicated. Effects in streams were minimal and were far less than those caused by severe spate conditions. Short-lived increases in drift and opportunistic feeding by brook trout, Salvalinus fontinalis Mitchell, were documented, but no significant depletion of bottom fauna was found.

Kingsbury, P.D. 1978. A study of the distribution, persistence and biological effects of fenitrothion applied to a small lake in an oil formulation. Forest Pest Manage. Inst. Inf. Rep. FPM-X-13, 56 pp.

Treatment of a small lake with 140 g fenitrothion/ha had little overall impact on lake biota. Little pesticide reached the deeper parts of the lake and persistence in surface waters was approximately one week. Fish caged at the surface accumulated moderate quantities of fenitrothion without apparent effects, and fish below the thermocline accumulated little more than trace amounts. Surface populations of zooplankton and phantom midge larvae, Chaoborus sp., were depressed for a short period. No substantial impact was found on benthic invertebrates, emerging insects or amphibians in the lake.

Kingsbury, P.D.; McLeod, B.B.; Mortensen, K. 1978. Impact of applications of the nuclear polyhedrosis virus of the red-headed pine sawfly, *Neodiprion lecontei* (Fitch), on nontarget organisms in 1977. Forest Pest Manage. Inst. Inf. Rep. FPM-X-11, 27 pp.

Nuclear polyhedrosis virus (NPV) trials carried out in the Renfrew, Ontario area were monitored for possible adverse side-effects upon selected nontarget organisms. An aerial application of 5.5 billion PIB/ha (emitted dosage rate) did not cause any adverse immediate or short term impact upon bird populations or honey bee colonies located in the treated areas. Some decrease in chironomid and baetid mayfly larvae occurred in a treated stream immediately after the virus application but postspray sampling indicated these declines were related to the nature of the streams studied and not to the virus application.

Tschaplinski, P.J.; Buckner, C.H. 1978. Toxicity and metabolism of fenitrothion in red-backed voles, *Clethrionomys gapperi* (Rodentia: Cricetidae). Forest Pest Manage. Inst. Inf. Rept. FPM-X-17, 215 pp.

The 96-h intraperitoneal LD_{50} of fenitrothion to Clethrionomys gapperi was 1330 mg/kg which is 12 times higher than that for laboratory strains of Mus musculus dosed intraperitoneally with technical-grade fenitrothion. Toxicities toward males and females were not significantly different. All showed symptoms of intoxication; 99% of the mortality occurred within 48 h of dose application.

All metabolites of fenitrothion metabolism in nonruminant mammals were identified and quantified by gas chromatography. At all doses, fenitrothion was rapidly metabolized and excreted. No body accumulation of residues was suggested. The toxicity of fenitrothion was not correlated with increasing proportion of the dose converted into fenitrooxon. The low toxicity to red-backed voles was due in part to rapid metabolic detoxication by two competitive mechanisms hydrolyzing fenitrothion at the P-O-aryl and P-O-alkyl bonds.

Holmes, S.B. 1979. Aquatic impact studies of a spruce budworm, *(Choristoneura fumiferana* Clemens) control program in the Lower St. Lawrence region of Québec in 1978. Forest Pest Manage. Inst. Inf. Rep. FPM-X-26, 34 pp.

Experimental and operational applications of fenitrothion at 0.210 kg AI/ha and aminocarb (Matacil®) at 0.053 kg AI/ha were monitored in Kamouraska County, Quebec to assess the impact of these treatments upon selected components of the aquatic environment. Applications at the dosage rate studied had little or no adverse effects on aquatic invertebrates or fish. Small increases in the drift of mayfly nymphs after a fenitrothion application, and of blackfly larvae after an aminocarb application, were documented. A slight depression in populations of heptagenid and baetid mayfly nymphs was noted after an application of aminocarb.

Kingsbury, P.D.; Kreutzweiser, D.P. 1979. Impact of double applications of permethrin on forest streams and ponds. Forest Pest Manage. Inst. Inf. Rept. FPM-X-27, 42 pp.

Aquatic impact studies of the synthetic pyrethroid, permethrin, applied to forest ponds and streams were conducted in 1978. Double applications of 17.5 g/ha permethrin resulted in substantial reductions of aquatic invertebrate populations, with the effects of the second applications significant in further reducing populations to a point at which recovery of numbers was delayed for at least a month and a half. No incidents of fish mortality were documented, however, fish food organisms were affected to an extent that the diet of native slimy sculpin, Cottus cognatus Richardson, populations shifted from various aquatic insects to almost exclusively midge larvae for a postspray period of at least 45 days. Return to a normal diet was evident by four months after treatment. Water analysis results indicated that permethrin residues never exceeded measured quantities of 2.6 µg/L and fell to below the limits of detection (0.25 µg/L) within 12 hours in streams and 48 hours in ponds.

Kingsbury, P.D.; McLeod, B.B. 1979. Terrestrial impact studies in forest ecosystems treated with double applications of permethrin. Forest Pest Manage. Inst. Inf. Rep. FPM-X-28, 55 pp.

Studies were conducted on the effects of two applications of 17.5 g/ha of the synthetic pyrethroid permethrin on breeding songbirds, small mammals, honeybees (Apis mellifera Linnaeus) and other nontarget terrestrial insects. Breeding songbirds inhabiting three different forest types (open plantation, coniferous forest, deciduous forest) were not affected by the treatments, nor were small mammals or their reproduction. Effects on honey bees were minimal, apparently due to a weather related lack of foraging activity after each treatment. A heavy knockdown of target and nontarget insect fauna occurred after the first permethrin application, but the effects of the second applications were much smaller. Permethrin residues reached peak levels of 0.12 ppm in forest soils, 0.24 ppm in spruce foliage, 0.32 ppm in pine foliage and 1.55 ppm in maple foliage.

Kingsbury, P.D.; McLeod, B.B. 1979. The impact of the 1978 spruce budworm, *Choristoneura fumiferana* Clemens, larvicidal timing trials in Québec upon forest avifauna. Forest Pest Manage. Inst. Inf. Rep. FPM-X-29, 77 pp.

Spruce budworm, Choristoneura fumiferana Clemens, larvicide timing trials were conducted in the lower St. Lawrence area of Quebec in 1978. Aminocarb was applied by aircraft at the dosage rate of 0.052 kg AI/ha when fifty percent of second instar budworm had emerged, peak fourth instar and five days following the fourth instar treatment. Breeding bird populations were studied throughout the experimental period. No immediate or short term impact was determined following any of the treatments and breeding territories remained intact. Population shift of some species resulted from factors other than insecticide treatment, and adverse weather caused noticeable fluctuations in singing and foraging activity.

Holmes, S.B.; Kingsbury, P.D. 1980. The environmental impact of nonyl phenol and the Matacil formulation. Part I. Aquatic ecosystems. Forest Pest Manage. Inst. Inf. Rep. FPM-X-35, 52 pp.

Field trials with nonyl phenol applied at 0.47 L/ha (the amount applied in the maximum seasonal dose of Matacil 1.8D) and Matacil® at 175 g AI/ha showed only small increases in invertebrate drift and with the Matacil® application a knockdown of terrestrial invertebrates. A reported kill of caged brook trout was not likely due to nonyl phenol poisoning. A review of the use of Matacil® as a spruce budworm control agent, environmental monitoring associated with Matacil® usage and toxicity data for freshwater organisms is included.

Kingsbury, P.D.; Holmes, S.B.; Millikin, R.L. 1980. Environmental effects of a double application of azamethipos on selected terrestrial and aquatic organisms. Forest Pest Manage. Inst. Inf. Rep. FPM-X-33, 32 pp.

Two consecutive applications of 0.070 kg AI/ha azamethiphos were studied to assess the impact of this compound on several components of the forest ecosystem. A general knockdown of terrestrial invertebrates was noted following each application. Apart from large increases in the drift of caddisfly larvae of the family Philopotomidae, the effect on aquatic invertebrates was minimal. Analysis of brook trout stomach contents indicated that, although some changes in the composition of the diet occurred, overall availability of food was not significantly reduced. Forest songbird populations were unaffected with no significant disruption of breeding activities.

Kingsbury, P.D.; Kreutzweiser, D.P. 1980. Dosage-effect studies on the impact of permethrin on trout streams. Forest Pest Manage. Inst. Inf. Rep. FPM-X-31, 51 pp.

Permethrin applications to small trout streams at dosage rates of 70.0 g and 35.0 g AI/ha resulted in massive disturbances to aquatic invertebrate populations and reduced numbers of benthic organisms up to and beyond the duration of the season of application. The impacts of 17.5 g and 8.8 g AI/ha Permethrin applications were of noticeably lesser magnitude and duration, and the recovery of benthic populations was documented within the season of application. The diet composition of brook trout, Salvelin fontinalis (Mitchill), was substantially altered by the two higher dosage applications, but did not induce reactions in the level of feeding activity or condition coefficients. No fish mortality resulting from the pesticide applications was observed. Permethrin was applied at rates of 70.0 g, 35.0 g, 17.5 ga and 8.8 g AI/ha to separate cold water streams of the Gaspe Peninsula, Quebec.

Kingsbury, P.D.; Kreutzweiser, D.P. 1980. Environmental impact assessment of a semi-operational Permethrin application. Forest Pest Manage. Inst. Inf. Rept. FPM-X-30, 47 pp.

A semioperational application of 17.5 g AI/ha permethrin to a 640 ha forest block in northern Ontario demonstrated environmental effects similar to those documented from previous studies of the same application rate. Noticeable increases in the number of drifting organisms occurred in the treatment block and 2.1 km downstream over a 24 hour period immediately after the spray, followed by a slight reduction in bottom fauna at the downstream station. Yellow perch, Perca flavescens (Mitchill), exposed to the application in wire cages indicated no lethal effects and did not accumulate detectable amounts of the pesticide. Arboreal and flying invertebrates were affected to a moderate degree, demonstrating a 24 to 36 hour increase in knockdown. Ground dwelling invertebrates experienced a slight reduction in activity immediately following the application, but returned to normal within 14 days. No measurable effects were encountered in small mammal populations.

Permethrin residues in water persisted for less than 96 hours and attained peak concentrations of 147.0 g/L in ponds and 2.5 g/L in streams, but accumulations and persistence of pesticide in bottom sediment were negligible. Insecticide residues in foliage, soil, and litter were more stable and remained at detectable concentrations to the end of the 58-day sampling period.

Kingsbury, P.D.; McLeod, B.B. 1980. The impact of spruce budworm (*C. fumiferana* Clemens) control operations involving sequential insecticide applications upon forest avifauna in the lower St. Lawrence Region of Québec. Forest Pest Manage. Inst. Inf. Rep. FPM-X-34, 64 pp.

Operational forest protection programmes in 1977 and 1978 in the Province of Quebec employed the sequential application of three insecticides (1977) and the sequential use of three different spray aircraft (1978). Forest avifauna were studied to determine possible adverse effects resulting from either operation. No bird mortality resulted from either operation and breeding territories of selected birds remained occupied throughout both operations.

Holmes, S.B.; Millikin, R.L.; Kingsbury, P.D. 1981. Environmental effects of a split application of Sevin-2-oil . Forest Pest Manage. Inst. Inf. Rept. FPM-X-46, 58 pp. + appendices.

A split application of Sevin-2-Oil had no significant adverse effect on either forest songbirds or wild pollinators, and only a slight knockdown effect on nontarget terrestrial arthropods. Carbaryl residues as high as 313.7 ppb and 122.6 ppb were detected in stream water immediately after the first and second applications respectively. Residues declined rapidly but were still detected (0.9 ppb) up to 10 days after the completion of spraying. Although both treatments resulted in disruptions in the normal diurnal drift pattern of aquatic invertebrates, the overall effect on benthic invertebrate populations was negligible. Analysis of brook trout and slimy sculpin stomach contents indicated that availability of food was not significantly reduced. No mortality was recorded among native brook trout caged in the treatment stream for up to 10 days after the second application. Sevin-2-Oil was applied twice at a dosage rate of 280 g/ha/application to a 400 ha spray block located near Allardville in Gloucester County, New Brunswick.

Kingsbury, P.D.; McLeod, B.B. 1981. Fenitrothion and forest avifauna studies on the effects of high dosage applications. Forest Pest Manage. Inst. Inf. Rept. FPM-X-43, 27 pp.

No bird mortality or immediate or short-term reductions in populations or activity of forest avifauna were recorded following experimental or semioperational applications of fenitrothion applied twice within a five day interval at 0.280 kg AI/ha. Fenitrothion at this dosage rate was applied to a 930 ha block in Ontario by small fixed wing aircraft in 1976, and to a 120,960 ha block in Quebec by multi-engine aircraft in 1977. Forest bird populations inhabiting various forest sites were monitored each year to evaluate spray impact.

Kingsbury, P.D.; McLeod, B.B.; Millikin, R.L. 1981. The environmental impact of nonyl phenol and the Matacil formulation. Part II. Terrestrial ecosystems. Forest Pest Manage. Inst. Inf. Rep. FPM-X-36, 67 pp.

Conventional double applications of Matacil® and seasonal maximum applications of nonyl phenol and Matacil had no significant effects on forest songbird populations,

and small mammal breeding activity was not affected by the seasonal maximum Matacil treatment. Nonyl phenol did not exhibit any apparent insecticidal effects on terrestrial invertebrates inhabiting trees or honey bee colonies. Conventional Matacil applications caused a moderate knockdown of terrestrial arthropods over a two day period. A seasonal maximum application of Matacil resulted in a large knockdown of terrestrial arthropods persisting for a similar period.

Holmes, S.B.; Kingsbury, P.D. 1982. Comparative effects of three Matacil field formulations on stream benthos and fish. Forest Pest Manage. Inst. Inf. Rept. FPM-X-55, 51 pp.

The effects of three Matacil® field formulations and some of their components on the invertebrate fauna of a cold water trout stream were studied near Searchmont, Ontario. Treatments were made by hand applying the test materials to a section of stream using a Micron ULVA sprayer. Applications of Matacil® 1.8D + ID 585 and Matacil® 1.8F + Atlox 3409 F + water both resulted in increased drifts and population reductions of some invertebrate taxa. Collembola and Gerridae appeared to be most affected by the Matacil 1.8D + ID 585 treatment and Simuliidae, Leuctridae, Baetidae, Philopotamidae and Hydroptilidae by the Matacil 1.8F + Atlox 3409F + water treatment. Peak aminocarb levels in water following these treatments (35.4 and 256.1 ppb respectively) were higher than those measured following operational applications of Matacil in Quebec and Newfoundland. No impacts were evident following applications of Matacil 1.8F + ID 585 and Matacil 1.8F + Atlox 3409F + water, for which peak levels of aminocarb in water were 127.2 and 29.2 ppb respectively. Although an application of Sunspray 7-N + ID 585 resulted in increased drifts of Collembola and Leuctridae, no impacts were associated with an application of Sunspray 7-N + Atlox 3409F + water, even though applied at a higher dosage rate. There was no mortality of rainbow trout fingerlings held in cages in the treated stream sections. Fish did accumulate aminocarb residues in their tissues, however. Bioaccumulation ratios were 0.48 for the Matacil 1.8D + ID 585 treatment, 0.25 for the Matacil 1.8F + ID 585 treatment and 0.50 for the Matacil 1.8F + Atlox 3409F + water treatment.

Kreutzweiser, D.P. 1982. The effects of permethrin on the invertebrate fauna of a Québec forest. Forest Pest Manage. Inst. Inf. Rept. FPM-X-50, 44 pp + appendices.

Both a single and double application of 17.5 g AI/ha Permethrin resulted in catastrophic drift of aquatic invertebrates and substantial depletion of benthos in streams within the application blocks and up to 2 km downstream. Despite massive disturbances of benthos, repopulation of bottom fauna was evident within 2.5 months and was virtually complete at the taxonomic level studied within 3.5 months. Terrestrial arthropods demonstrated a light to moderate pesticide-induced knockdown from stream bank foliage and forest canopy for up to 48 hours after each application. There was no measurable impact on the activity of ground dwelling invertebrates or small mammals. Permethrin residues attained peak levels of 1.35 µg/L in standing water and 1.94 µg/L in flowing water and persisted at low concentrations for up to 96 hours postspray. Accumulations of residual permethrin were negligible in sediment,

but were higher and more persistent in forest litter. Four 400 ha blocks in Kamouraska County in the Lower St. Lawrence Region of Quebec were treated with 17.5 g AI/ha permethrin emitted in 1.46 L/ha. Two blocks received a single application and two blocks received two treatments at nine or ten day intervals.

Kreutzweiser, D.P.; Kingsbury, P.D. 1982. Recovery of stream benthos and its utilization by native fish following high dosage permethrin applications. Forest Pest Manage. Inst. Inf. Rep. FPM-X-59, 20 pp + appendices.

Bottom fauna and native fish populations were sampled during four consecutive years following high dosage experimental permethrin applications to coldwater streams in the Gaspe Peninsula, Quebec. Stream benthos density and diversity returned to normal levels within one year of a 35.0 g AI/ha permethrin application, but remained suppressed for up to 16 months in a stream treated with 70.0 g AI/ha permethrin. The feeding activity of native fish in the two treated streams reflected the availability of food organisms. As the abundance and diversity of benthic invertebrates increased, the selection of various fish food organisms by both brook trout, Salvelinus fontinalis, and slimy sculpins, Cottus cognatus, showed comparable increases. Pesticide-induced changes in diet composition did not appear to adversely affect the condition of brook trout and no significant differences ($p < 0.05$) were found in ovary production of female trout in the treated and control streams 16 months after the permethrin applications.

Millikin, R.L.; McLeod, B.B. 1982. Environmental impact assessment of experimental spruce budworm adulticide trials. Part 1. Effects on forest avifauna. Forest Pest Manage. Inst. Inf. Rep. FPM-X-54, 108 pp.

Adulticide treatments involving various spray regimes of phosphamidon (Dimecron®) and aminocarb (Matacil®) had no obvious harmful effects on forest songbird populations on the whole. Small population reductions were noted for the ruby-crowned kinglet, Regulus calendula, and Tennessee warbler, Vermivora peregrina, after a single application of phosphamdion; and the Tennessee and Cape May warblers, Dendroica tigrina, after 5 consecutive applications within 8 days. An immature Purple finch, Carpodacus purpureus, may have suffered pesticide poisoning in an area receiving three applications of aminocarb. Eight experimental programs of aerial application of pesticides for adult spruce budworm suppression were monitored from 1974 to 1977 in New Brunswick.

Szeto, S.; Holmes, S.B. 1982. The lethal toxicity of Matacil 1.8 to rainbow trout and its *in vivo* metabolism. J. Environ. Sci. Health B17(1):51-61.

Fingerling rainbow trout (Salmo gairdneri Richardson) were used to determine the lethal toxicity of Matacil® 1.8F and Matacil® 1.8D ready-to-use formulations. The 96-h LC_{50}s were 21.3 mg/L for water-based Matacil® 1.8F; 29.1 mg/L for oil-based Matacil 1.8F; and 0.36 mg/L for Matacil® 1.8D.

Aminocarb (4-dimethylamino-m-tolyl N-methylcarbamate) and MA (4-methylamino-m-tolyl N-methylcarbamate) were detected in fish tissue 96 h after exposure. More than 50% of the total residues (Aminocarb + MA) were the parent compound. The bioaccumulation ratio ranged from 1.70 to 3.32 at different concentrations of aminocarb. Both aminocarb and MA were rapidly eliminated after the fish had been transferred to clean water; the total residue declined by more than 90% in 72 h and became nondetectable in 96 h.

ENVIRONMENTAL CONCERNS: CHEMICAL ACCOUNTABILITY

Sundaram, K.M.S.; Hopewell, W.W. 1977. Fate and persistence of aminocarb in conifer foliage and forest soil after simulated aerial application. Forest Pest Manage. Inst. Inf. Rep. FPM-X-6, 41 pp.

The rate of disappearance of aminocarb residues in spruce foliage and forest soil was studied under natural meteorological conditions. The aminocarb formulation was applied as a simulated aerial spray at a rate of 3.5 L/ha containing 57 g AI. Aminocarb residues were determined by gas chromatographic analysis, using a Tracor Model 550 chromatograph fitted with a Hall detector, over a 69-day period following treatment. Initial concentrations of more than 10 ppm aminocarb in foliage and 7 ppm in soil and half-life times of 6 and 2 days respectively, had dropped to trace or nondetectable levels within 47 and 27 days. Aminocarb was found to be labile and dissipated rapidly under normal weathering conditions. Details of the extraction and chromatographic determination of aminocarb residues in foliage and soil are included.

Sundaram, K.M.S.; Szeto, S.; Hindle, R. 1978. Isolation and analysis of aminocarb and its phenol from environmental waters. Forst Pest Manage. Inst. Inf. Rept. FPM-X-18, 28 pp.

Recovery of aminocarb (4-dimethylamino-m-totyl methylcarbamate) and its phenolic metabolite [aminocarb phenol, (4-dimethylamino-m-cresol)] from aqueous solution by column chromatography on Amberlite XAD-2 resin was investigated. Absorption of the chemicals on the column was influenced by the pH of the solution and a correlation existed between recovery levels and pH. The absorbed parent material was stable in the column by suitable elution and quantitation by Hall gas-liquid chromatography (GLC) showed near quantitative recoveries for the parent material. Optimization of experimental conditions, column and GLC parameters, recovery levels, standard deviations and minimum detection levels of the chemicals are discussed. The procedure developed is simple and readily applicable to environmental monitoring and quality control programs.

Sundaram, K.M.S.; Szeto, S. 1979. A study on the lethal toxicity of aminocarb to freshwater crayfish, and its *in vivo* metabolism. J. Environ. Sci. Health B14(6): 589-602.

Adult crayfish (Orconete limosus) were exposed to 0.1, 1.0, 5.0, 10.0, 25.0, 30.0, 40.0, 50.0, and 60.0 ppm of aminocarb in water at 15°C under laboratory conditions for 144 h. No apparent behavioral changes were observed in crayfish exposed to 0.1, 1.0 and 5.0 ppm of aminocarb during the experiment. Symptoms of acute toxicity were apparent at concentrations ≥10 ppm, and mortality occurred at and above 25 ppm. The LC_{50}, 96 h, to adult crayfish was about 33 ppm.

The parent compound and its metabolites, MA (4-methylamino-m-tolyl N-methylcarbamate) and AM (4-amino-m-tolyl N-methylcarbamate), were detected in crayfish 96 h after exposure to various concentrations of aminocarb. The primary metabolite detected was MA which accounted for 75% to 95% of the body residue. The highest total residue (Aminocarb + MA + AM) was 40 ppm detected in crayfish exposed to 60 ppm of aminocarb for 96 h.

Sundaram, K.M.S.; Szeto, S.; Hindle, R. 1979. Evaluation of Amberlite XAD-2 as the extractant for carbamate insecticides from natural water. J. Chromatogr. 177: 29-34.

A rapid and sensitive analytical technique to quantify carbamate insecticides at nanogram levels is reported using resin column and sorption, and desorption followed by N-P gas-liquid chromatography (GLC) analysis. The carbamates were extracted from natural water by percolation through a column of Amberlite XAD-2, followed by elution with ethyl acetate. The carbamate residues were directly analyzed by GLC with a Tracor Model 702 N-P detector. The recoveries for several carbamates including aminocarb, mexacarbate, carbaryl, propoxur, carbofuran, pirimicarb and methiocarb were from 85 to 108% at 1.0 and 0.01 ppm levels. Only 41 to 58% was recovered for methomyl.

The extraction efficiency of Amberlite XAD-2 was pH-dependent as indicated in the extraction of aminocarb. More than 90% of the added aminocarb was recovered from phosphate buffer by the described method at pH 2.0 to 7.5 at 5.0 and 0.5 ppm levels.

Sundaram, K.M.S.; Szeto, S.Y.; Hindle, R. 1980. Detection of aminocarb and its major metabolite by thin layer chromatography. J. Chromatogr. 194: 100-103.

Sundaram, K.M.S.; Szeto, S.; Hindle, R.; MacTavish, D. 1980. Residues of nonyl phenol in spruce foliage, forest soil, stream water and sediment after its aerial application. J. Envir. Sci. Health B15(4): 403-419.

Nonyl phenol, a major component of the Matacil (aminocarb) formulation, was mixed with insecticide diluent 585 and applied at 0.47 L/ha by a fixed-wing aircraft to a mixed coniferous forest in Algoma District, Ontario. Residues in white spruce foliage were the highest 1 h after spraying (18.90 ppm) and declined to 60% in the next two hours. After 30 days only 3% of the highest concentration recorded was observed. No detectable levels (<0.20 ppm) of nonyl phenol were found after 62 days. No residues were detected in any forest soil sample collected after spraying.

Nonyl phenol residues were about 9 ppb in the stream water 1 h after its application and declined to 50% in the next two hours. Only trace amounts (less than 2.0 ppb) were detected after 5 days and no residues were detected in any water sample taken beyond this time. Residues at trace level (less than 0.10 ppm) were detected in only one sediment sample taken 4 hours after spraying.

Szeto, S.Y.; Sundaram, K.M.S. 1980. Simplified method for the analysis of some carbamate insecticides in foliage, forest soil and fish tissue by direct gas-liquid chromatography. J. Chromatog. 200:179-184.

A simplified and sensitive method for the analysis of eight carbamate insecticide residues in foliage, forest soil and fish tissue by direct gas-liquid chromatography (GLC) is described. After fortification, the carbamate residues were extracted from the natural substrates by homogenization in ethyl acetate. The interfering coextractives present in the crude extracts were removed by filtration through Whatman GF/A glass microfibre filters after coagulation. The carbamate residues were re-extracted into dichloromethane and directly analyzed intact by GLC with a Tracor Model 702 nitrogen-phosphorus detector. The rate of recovery for aminocarb, carbofuran, carbaryl, methomyl, mexacarbate, pirimicarb and propoxur was better than 80% at 5.0 ppm and 0.50 ppm levels. Slightly less than 60% was recovered for methiocarb.

Sundaram, K.M.S.; Szeto, S. 1981. The dissipation of nonyl phenol in stream and pond water under simulated field conditions. J. Environ. Sci. Health B16(6):767-776.

The dissipation of 1.0 ppm nonyl phenol in stream and pond water, incubated in flasks at 16°C under simulated field conditions up to 44 days indicated that the half-life was 2.5 days if the flasks were open, and 16 days if they were closed. A transformed product was detected in the closed flasks.

Translocation of nonyl phenol in water occurred when treated water samples were incubated in the presence of sediment. After 10 days, nonyl phenol was detected only in the sediment, but not in water (detection limit = 10 ppb). About 80% of the nonyl phenol was degraded in 71 days, but no degradation occured if the water and the sediment were autoclaved prior to incubation.

Szeto, S.Y.; Sundaram, K.M.S. 1982. Behaviour and degradation of Chlorpyrifos-methyl in two aquatic models. Agricultural and Food Chemistry 30(6): 1032-1035.

At 15°C, (1) the movement, persistence, and degradation of 400 ppb of chlorpyrifos-methyl in the top 1.5-cm layer of flooded sandy loam soil (model I) and (2) the behavior and degradation of 200 ppb of this chemical in natural water (model II) were investigated for a period of 90 days. In model I chlorpyrifos-methyl was strongly adsorbed on the flooded soil; very little was desorbed and then dissolved in the water. The maximum concentration in the water was 1 ppb, detected after 0.7 days

(16.5 h) of incubation. Chlorpyrifos-methyl degraded readily in the flooded soil. The toxic breakdown product was 3,5,6-trichloro-2-pyridinol, which reached a maximum concentration in about 27 days and declined thereafter. The pyridinol was never detected in the water. Both compounds had almost completely disappeared in 90 days. In model II chlorpyrifos-methyl moved rapidly from the water to the flooded, clean soil. After incubation for 13 days, its concentration increased from nondetectable to a maximum of 560 ppb in the top 1.5-cm layer of the soil but decreased from 200 to 40 ppb in the water. Both the parent compound and its breakdown product were degraded readily in soil and water; only 0.1 and 10 ppb remained in the water and in the flooded soil, respectively, after incubation for 83 days.

COMPLEMENTARY SERVICES: DISEASE DIAGNOSIS

Burke, J.M. 1983. Micro-organisms infecting the large aspen tortrix, *Choristoneura conflicatana* Wlk. (Lepidoptera: Tortricidae). Forest Pest Manage. Inst. Inf. Rep. FPM-X-61, 14 pp.

Field-collected specimens of the large aspen tortrix, Choristoneura conflictana, are infected by several microorganisms, including granulosis virus, entomopoxvirus, three species of microsporidia, and three species of fungi. There are also mixed infections consisting of two or three microorganisms. Diagnostic results obtained between 1951 and 1978 demonstrate that widely separated geographic populations of this insect are affected by the same complement of microorganisms. Cross infection tests with microsporidia were carried out utilizing both laboratory-reared and field-collected insects. The results are inconclusive concerning the relationship of microsporidia in C. conflictana to those occurring in related insect species.

MISCELLANEOUS

Angus, T.A. In memoriam: A.M. Heimpel (1923-1979): an appreciation. J. Invert. Pathol. 36: 147-148.

Cadogan, B.L.; Laing, E. 1981. A study of *Balaustium Putmani* (Acarina: Erythraeidae) in apple orchards in southern Ontario. Proc. Entomol. Soc. Ont. 112: 13-22.

This study reports the numerical assessment of field populations of Panonychus ulmi Koch and its predator Balaustium putmani Smiley, which is bivoltine in southern Ontario. The prevalence of B. putmani suggests that its ability to survive in treated orchards might be due as much to the methods by which the pesticides are applied as to the cryptic habits of the predacius mites, and to the survival of alternate hosts, such as the eriophyid Aculus schlechtendali (Nal.), as to development of resistance to pesticides.

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Green, G.W. 1982. Biological control research in the Canadian Forestry Service. *In* Report from CCREM Pesticides Workshop, Toronto, March 1983, pp. 171-178.

Green, G.W.; Cayford, J.H. 1982. The development and registration of Forestry use pesticides. CPPA. Seminar on the use of herbicides and pesticides in Forest Management. Montreal, Jan. 1982.

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Green, G.W. 1983. Spruce budworm control options - current and future. *In* The spruce budworm problem in Ontario - real or imaginary. COJFRC Symposium Proceedings Report No. 0-P-11, pp 43-51.

The spruce budworm will continue to plague forest managers in Ontario as long as spruce and fir remain significant components of the province's forests. Spruce budworm control options currently available to forest managers are outlined in this paper and predictions are made concerning new pest control products and techngiues which may become available in the 1980s through continuing research and development.

Retnakaran, A. 1982. Do regulatory agencies unwittingly favour toxic pesticides. Bull. of Entomol. Soc. Am. 28(2): 146.

Retnakaran, A.; Grant, G.G.; Ennis, T.J.; Fast, P.G.; Arif, B.M.; Tyrrell, D.; Wilson, G.G. 1982. Development of environmentally aceptable methods for controlling insect pests of forest. Forest Pest Manage. Inst. Inf. Rep. FPM-X-62, 22 p.

Retnakaran, A. 1983. Spectrophotometric determination of larval ingestion rates in the spruce budworm (Lepidoptera: Tortricidae) Can. Entomol. 115:31-40.

The food intake of fourth, fifth, and sixth instar spruce budworm, Choristoneura fumiferana Clemens, was investigated by feeding larvae for 24 h artificial diet incorporating amaranth dye. Amaranth was selected because it followed Beer's law over a wide concentration range, mixed well with the meridic diet, could be extracted in ice-cold water, was not absorbed by larval tissue, had minimal feeding deterrence as well as marginal adverse chronic effects on the larvae, and finally had negligible effect on ingestion rate over 1 24-h period. The results indicated that 6th instars consumed 20 times and 5th instars 3 times as much as 4th instars, but when compared

on a body weight basis the ingestion rate was similar in all three instars. Temperature and photoperiod influenced the rate of food intake. The application of these findings in assessing defoliaton to the forests as well as estimating dosage of pesticides for control of this species are discussed.

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